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The Reliability Of The Navicular Drop Test and Its Transferability To Dynamic Movement

Joshua Krispin

THE RELIABILITY OF THE NAVICUALR DROP TEST AND ITS TRANSFERABILITY TO DYNAMIC MOVEMENT

by

JOSHUA KRISPIN

(Under the Direction of Dr. Li Li)

ABSTRACT

Background: Navicular drop can be defined as the distance the navicular tuberosity moves from a standing weight bearing to a standing neutral position, as the subtalar joint moves from a relaxed position to a neutral position. Navicular drop is an important measurement for clinicians used to describe foot function, pronation, and excessive movement seen in several pathologies. Objective: The purpose of this study is to see if navicular drop is influenced by mode or speed of locomotion, if it is will there be other influences such as the forefoot and heel soft tissue, and will those factors influence those measures. The secondary purpose of this study is to see if the static and dynamic measures of navicular drop will be reliable. Methods: This study included fourteen 21-25 year old recreationally active individuals. Three reflective markers were placed on the medial aspect of the participant's right foot. Static measure of navicular drop was taken, and then the participants were instructed to walk, and run on a treadmill at different speeds. Statistical Analysis: Statistical Package for Social Sciences (SPSS) software version (23.0) was used. Intraclass correlation coefficients (2,1) model were analyzed in SPSS to determine reliability values of the static and dynamic measures of navicular position and drop. An Analysis Of Variance (ANOVA) was analyzed for differences under different conditions. Results: Navicular drop was higher during running (14.83 ±

0.61mm) compared to walking (8.19 ± 0.52mm) $P<0.05$. Drop of the triangle was higher in running (7.74 ± 0.26mm) compared to walking (4.37 ± 0.19mm) $P<0.05$. Conclusion: Navicular drop during dynamic movement is greater than the static measure, and navicular drop is greater during running compared to walking.

INDEX WORDS: Navicular drop, Dynamic movement, Fat pads

THE RELIABILITY OF THE NAVICULAR DROP TEST AND ITS

TRANFERABILITY TO DYNAMIC MOVEMENT

by

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CHAPTER 1

INTRODUCTION

Static measures of the lower extremity are thought to help understand functional occurrences and abnormalities during gait.(McPoil & Cornwall, 1996) It can be hypothesized that static measurements can predict dynamic movement of the lower extremity and foot.(McPoil & Cornwall, 1996) One such measurement is the navicular drop test, previously utilized as a clinical assessment of foot mobility and pronation.(Loudon, Jenkins, & Loudon, 1996; McPoil et al., 2008)

Navicular drop can be defined as the distance the navicular tuberosity moves from a standing weight bearing to a standing neutral position, as the subtalar joint moves from a relaxed position to a neutral position. (Eslami, Damavandi, & Ferber, 2014) Navicular drop is an important measurement for clinicians used to describe foot function, pronation, and excessive movement seen in several pathologies.(Egloff M, 2015) Subtalar joint motion has been suggested to be the best clinical indicator to represent overall foot function, and can be assessed by measuring navicular drop.(Eichelberger, 2015)

The navicular drop test was first described by Brody who noted that it was helpful in evaluating the amount of foot mobility, specifically foot pronation in runners.(Brody, 1982) The typical measurement for navicular drop ranges from 5 to 9 mm. Values less than 4 mm represent a high arch, while values greater than 10 mm represent a low arch.(Eslami et al., 2014)

In 2014, Eslami and colleagues conducted a study in which the navicular drop test was compared to the stance phase of running.(Eslami et al., 2014) Static measures of navicular drop were taken, then participants ran on a treadmill to a cadence of a

metronome.(Eslami et al., 2014) Observations showed that there was a significant correlation ($P=.01$) between navicular drop and tibial internal rotation.(Eslami et al., 2014)

Nielsen and colleagues conducted a study, which studied navicular drop and walking.(Nielsen, Rathleff, Simonsen, & Langberg, 2009) Static measures of navicular drop were taken, and then participants walked on a treadmill at a self selected pace. (Nielsen et al., 2009) The study looked at the correlation between foot length and navicular drop, and observed a positive correlation between foot length and navicular drop ($P<.001$). (Nielsen et al., 2009) More studies need to be conducted to determine if there is a relationship between static and dynamic measures of navicular drop.

Previous studies have investigated tissue deformation in the foot with dynamic movement. One study looked at heel strike of running with participants barefoot and being in shoes.(De Clercq, Aerts, & Kunnen, 1994) The results of the study showed that the heel pad deforms to a maximal percentage of $60.5 \pm 5.5\%$ while being barefoot, and $35.5 \pm 2.5\%$ while shoe running. (De Clercq et al., 1994) The second study looked at the heel pads and arch deformation during the mid stance of walking.(Qian, Ren, & Ren, 2010) Not only did the heel pads compress, the study states the five branches of the plantar fascia extend and deform at different times.(Qian et al., 2010) The results of these studies suggest when taking static or dynamic measurements, soft tissue deformations need to be considered.

Picciano and colleagues conducted a study looking at the reliability of the navicular drop test. The navicular drop test demonstrated fair to good reliability, with

intrarater interclass correlation values of 0.61-0.79 and a inter-rater interclass correlation value of 0.57.(Picciano, Rowlands, & Worrell, 1993)

It is hypothesized that static measures can predict dynamic movement in the lower extremity and foot.(McPoil & Cornwall, 1996) The abilities of static measurements to predict dynamic foot motion could have important implications.(McPoil & Cornwall, 1996) To our knowledge, there have been very few studies that have used a static measure of navicular drop and compared it to a dynamic measure while walking and running at different speeds. The purpose of this study is to see if navicular drop is influenced by mode or speed of locomotion, if it is will there be other influences such as position of the forefoot and heel soft tissue, and will those factors influence those measures. The secondary purpose of this study is to see if the static and dynamic measures of navicular drop will be reliable.

The hypotheses of the study are mode of locomotion and speed of locomotion will affect the navicular position and drop, the second hypothesis is navicular position and drop during dynamic movement is influenced by the change of the fat pads around the toe and heel under different conditions, and the third hypothesis is static and dynamic measure of navicular drop will be reliable measures.

CHAPTER 2

METHODS

Fourteen participants participated in this study, with a mean age of 22.64 (SD= 1.28) years, 160.56 (SD= 43.1) cm, and 71.96 (SD = 13.95) kg. Participants were recruited from graduate and undergraduate courses at a university in South Georgia. Experimentation procedures were explained to all participants who volunteered and signed the informed consent approved by Institutional Review Board. Recreationally active was defined as participating in at least 20 minutes of physical activity three times per week.(Brown & Mynark, 2007) According to the American Academy of Sports Medicine, physical activity can be defined as any bodily movement produced by the contraction of skeletal muscles that results in a substantial increase in caloric requirements over resting energy expenditure.(Lippincott, Williams, & Wilkins, 2014) The inclusion criteria allowed for those with no apparent neuromuscular pathology, college aged non-athlete, and was not a participant in the pilot of this study. The exclusion criteria were history of lower extremity injury in the past 6 months, history of lower extremity surgery, and answered yes to any question on the Physical Activity Readiness Questionnaire.

The materials used in the study include a small ruler, three index cards per participant and a black ink pen to mark the navicular tuberosity, which will be used to take measurements of navicular drop as described by Brody (Brody, 1982). Three reflective markers were used to mark the first metatarsophalangeal joint, navicular tuberosity, the medial aspect of the calcaneus.

The study utilized a Biodex RTM 500 treadmill (Biodex Medical Systems, Inc. Shirley, New York) for the walking and running trials. Sentech USB camera viewing software STC-MBA5MUSB3 was used to capture the walking and running trials (Sensor Technologies America Carroltion, TX). Innovision systems MaxTRAQ version 2.2 analysis software (Innovision Systems Columbiaville, MI) was used to digitize and measure the outputs created by the reflective markers.

This study examined the right foot of each participant, and the participants were barefoot. After the markers were placed on the participant, the participant stood on their right foot in a relaxed full weight bearing position on the treadmill, and this was captured on camera. After that was captured the participant was asked to invert and evert their foot until the investigator found subtalar neutral. When the participant was in subtalar neutral, the position was recorded on camera. The difference between the relaxed and subtalar neutral positions were subtracted from one another and that value was the navicular drop.

All data were collected at 60Hz. Prior to the trials, the participant walked at 1.11 m/s (2.5 MPH) for one minute to warm up. After the warm up period the participant was instructed to walk at 1.34 m/s (3 MPH), 1.78 m/s (4 MPH), and 2.23 m/s (5 MPH), then run at 2.23 m/s (5 MPH), 2.68 m/s (6 MPH), and 3.13 m/s (7 MPH). The overlap in speeds was to determine if navicular drop was affected by speed, or mode of locomotion. After the participant became comfortable with the speed, data were collected for 10-12 s, or recording 7 footfalls for each participant. Between each walking and running trial, the participant was given a brief rest period. The protocol was balanced for each participant to try and prevent any practice or fatigue effect. The first participant walked at 1.34 m/s, 1.78 m/s, and 2.23 m/s, and ran at 2.23 m/s, 2.68 m/s, and 3.13 m/s, then the next

participant started with 1.78 m/s then went through the protocol and ended with 1.34 m/s. The participants were asked to return in 7 days to complete the study again, allowing for the reliability to be determined.

After the data was collected, data was processed and digitized using the Innovision Systems MaxTRAQ Version 2.2 analysis software. The markers were digitized during static and dynamic movement, and produced a measure of navicular position, heel position, and toe position in pixels. A known distance was used in millimeters to digitize the data from pixels to millimeters.

The outcome variables of the study were navicular Y, which is the absolute height, and the vertical axis of the navicular marker, heel Y which is the vertical axis of the heel marker, and toe Y which is the vertical axis of the great toe marker. TH drop is the vertical drop of the navicular marker within the triangle. The triangle is consisted of the toe Y, navicular Y, and heel Y markers. The triangle is used to measure the height of the navicular position to see if any fat pad or arch deformation occurs. Navicular drop consists of the difference of the relaxed position to the subtalar neutral position, which was recorded on camera. Navicular drop was calculated during dynamic movement by obtaining the lowest point of the navicular position during each walking and running trial, and subtracting that lowest point value from that participant's relaxed navicular position.

The speed of movement is described by low, medium, and high. Low speed is walking at 1.34 m/s and running at 2.23 m/s. Medium speed is walking at 1.79 m/s and running at 2.68 m/s. High speed is walking at 2.23 m/s and running at 3.12 m/s.

After the data was processed, Statistical Package for Social Sciences (SPSS) software version (23.0) was used, to analyze all measurements using an alpha level of

0.05. Multivariable general linear models were used to calculate if mode of locomotion, velocity, or the interaction of mode of locomotion and velocity were significant. Two-way random (2,1) intraclass correlation coefficients were calculated for static navicular drop, navicular position, and navicular drop during velocity. Effect sizes were calculated for all statistically significant findings using Cohen's d.(Cohen, 1988)

CHAPTER 3

RESULTS

The following results will be represented by the mean and standard error. The hypothesis that navicular position and drop would be affected by mode and speed of locomotion is supported by the results of the study. Navicular Y was lower to the ground during running (166.04 ± 0.91mm) compared to walking (172.68 ± 0.96mm) ($F(1,27)= 95.16$, $d= 0.78$, $P< .05$).

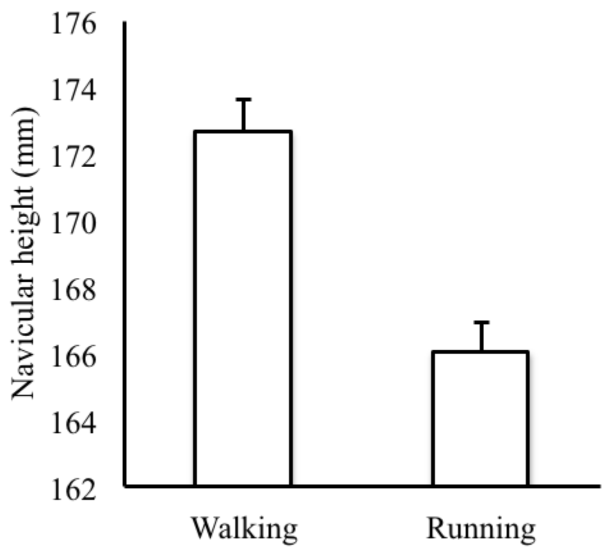

Figure 1: The vertical height of the marker on the navicular bone in millimeters while walking and running. Cohen's effect size d=0.78.

Navicular Y was significantly lower to the ground during medium speed (168.59 ±1.24mm) compared to high speed (168.93 ± 1.27mm), and compared to low (170 ± 1.16mm) ($F(1,27)=8.48$, $d= 0.22$, $d= 0.18$, $d=0.036$, $P<.05$) on a linear trend.

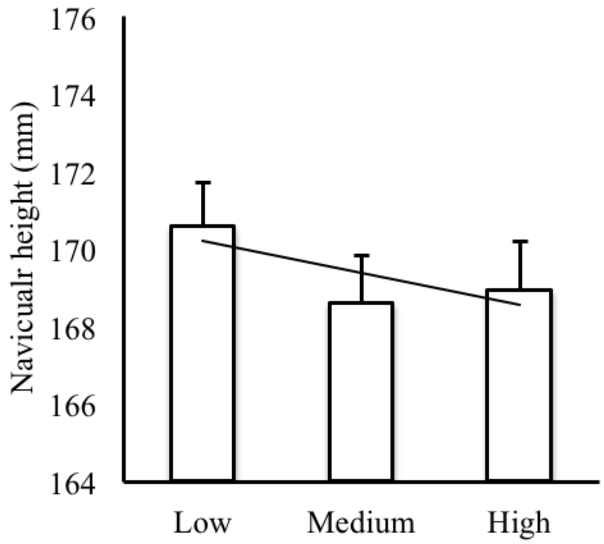

Figure 2: The vertical height of the marker on the navicular bone in millimeters while walking and running at different speeds was significant on a linear trend. Cohen's effect size low to medium d=0.22, low to high d=0.18, medium to high d=0.036.

The overall absolute drop of the navicular was significantly higher with running (14.83 ± 0.61mm) compared to walking (8.19 ± 0.52mm) ($F(1,27) = 95.16$, d= 1.28, $P<.05$). The drop of the navicular is significantly higher among medium speed (12.23 ± 0.82mm) compared to high speed (11.94 ±0.88mm), compared to low (10.31 ± 0.75mm), ($F(1,27) = 8.48$, d= 0.34, d=0.27, d=.053, $P<.05$) on a linear trend.

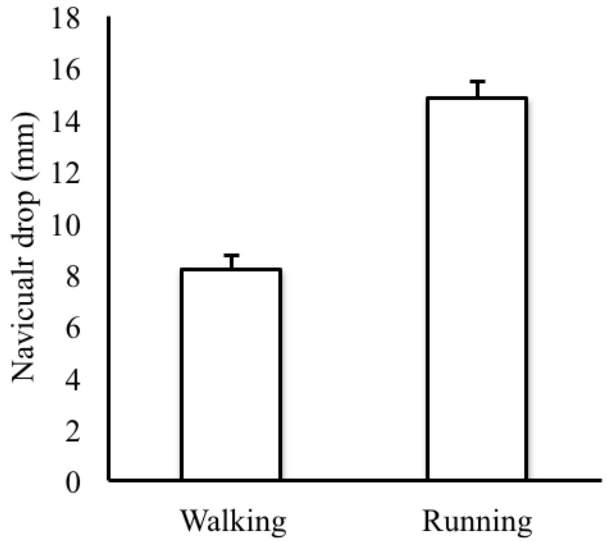

Figure 3: The absolute drop of the navicular in millimeters while walking and running. Cohen's effect size d= 1.28.

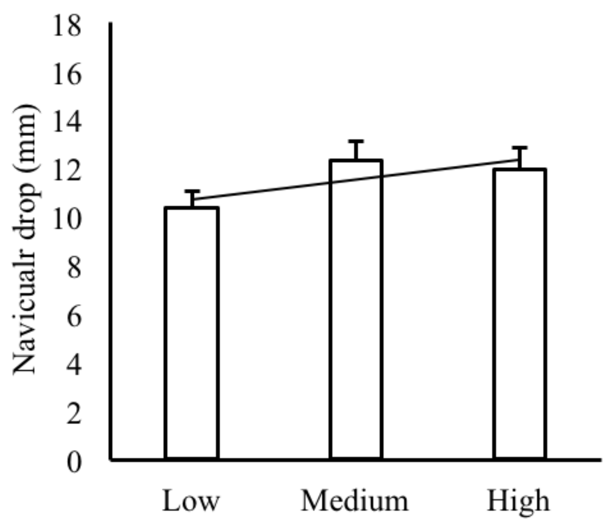

Figure 4: The absolute drop of the navicular in millimeters while walking and running at different speeds was significant on a linear trend. Cohen's effect size low to medium d= 0.34, low to high d=0.27, and medium to high d=0.053

The hypothesis that navicular drop during dynamic movement is influenced by the change of the fat pads around the toe and heel under different conditions is supported

by the results. TH drop was significantly higher in running (7.74 ± 0.26mm) compared to walking (4.37 ± 0.19mm) ($F(1,27) = 164.64$, d= 1.56, $P<.05$). TH drop had a significant interaction between mode and velocity ($F(1,27) = 6.59$, d= $P<.05$) on a quadratic trend.

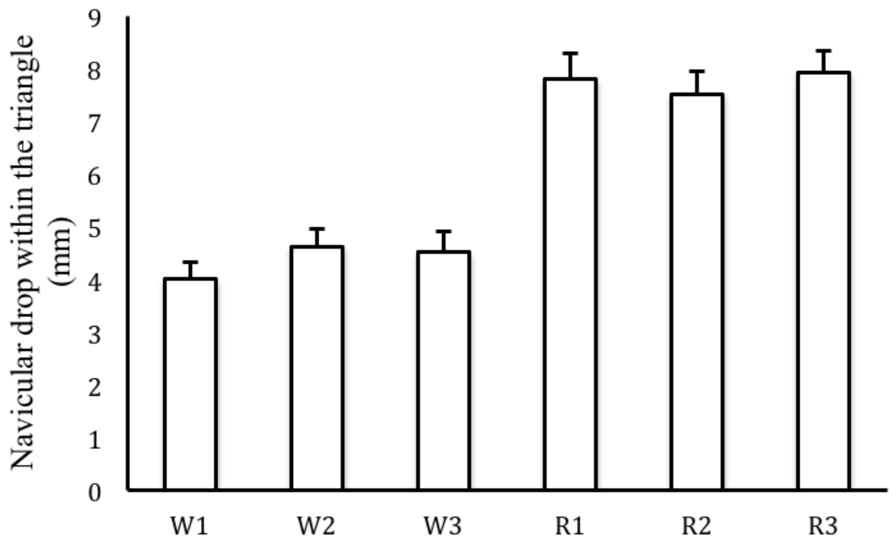

Figure 5: The drop of the navicular in millimeters within the triangle while walking and running at different speeds

Heel Y was significantly lower to the ground during running (157.58 ± 0.77mm), compared to walking (159.24 ± 0.67mm) ($F(1,27) = 6.24$, d= 0.25, $P<.05$). Heel Y was significantly lower to the ground during medium speed (157.82 ± 0.97mm) compared to high speed (158.05 ± 0.89) mm compared to low (159.36 ± 0.81mm) ($F(1,27) = 6.22$, d=0.23, d=0.20, d=0.033, $P<.05$) on a linear trend.

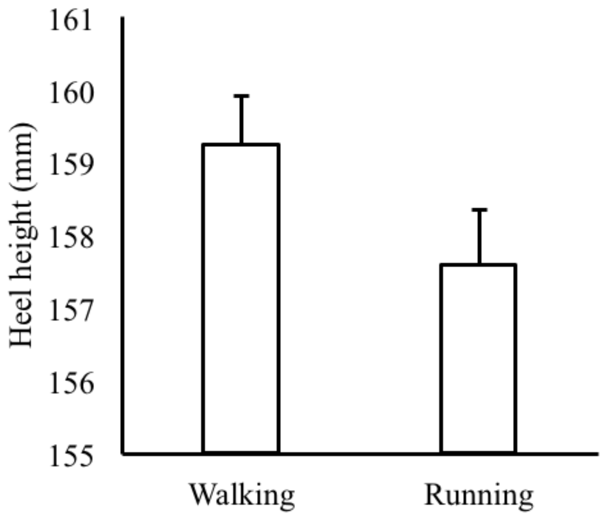

Figure 6: The vertical height of the maker on the heel in millimeters while walking and running. Cohen's effect size d=0.25.

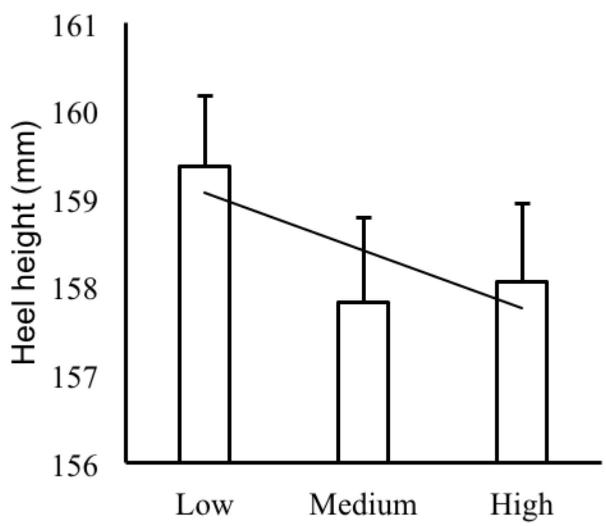

Figure 7: The vertical height of the marker on the heel in millimeters while walking and running at different speeds was significant on a linear trend. Cohen's effect size low to medium d=0.23, low to high d=0.20, and medium to high d=0.033.

Toe Y was significantly lower to the ground during running (146.07 ± 0.78mm) compared to walking (150.96 ± 0.70mm) (F(1,27) = 60.60, d= 0.72, P<.05). Toe Y was significantly lower to the ground during medium speed (147.58 ± 1.02mm), compared to high speed (148.31 ± 0.97mm), compared to low (149.64 ± 0.89) mm (F(1,27) =4.75, d=0.29, d=0.19, d=0.098, P<.05) on a quadratic trend.

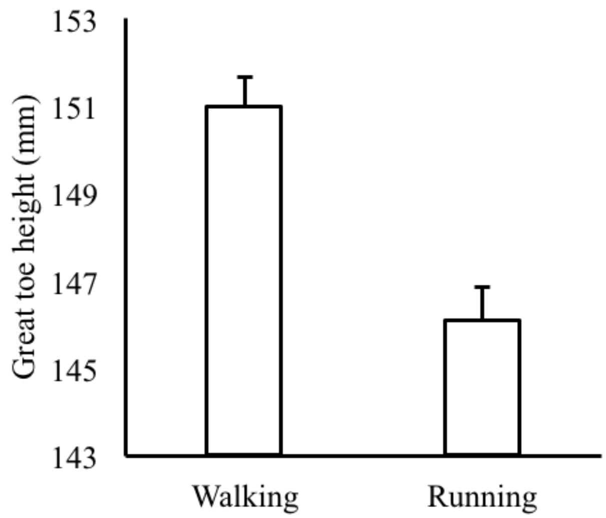

Figure 8: The vertical height of the marker on the great toe in millimeters while walking and running. Cohen's effect size d=0.72.

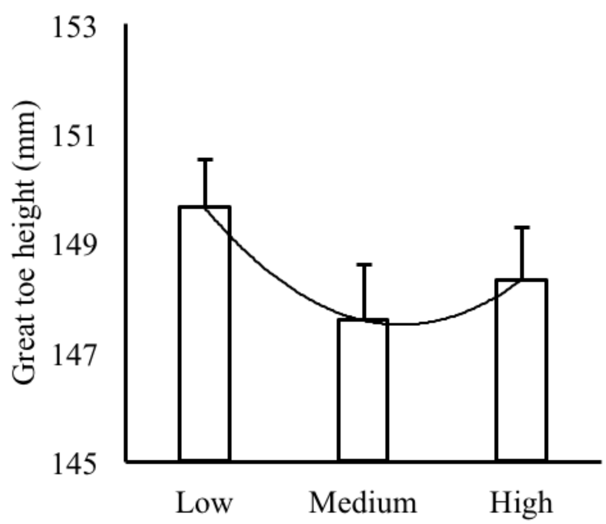

Figure 9: The vertical height of the marker on the great toe in millimeters while walking and running at different speeds was significant on a quadratic trend. Cohen's effect size low to medium d=0.29, low to high d=0.19, and medium to high d=0.098.

The hypothesis that static and dynamic measure of navicular height and drop will be a reliable measure is supported by some of the results of the study. The static measure of navicular drop had poor reliability (ICC= 0.21) with day one measure (5.57 ±

0.94mm), compared to day seven (5.17 ± 1.2mm). Navicular Y had fair to good reliability across different speeds. Walking represented fair reliability, 1.34 m/s (ICC=0.57) day one (175.6 ± 2.9mm), compared to day seven (172.8 ± 1.9mm), 1.79 m/s (ICC=0.51) day one (173.5 ± 2.7mm), compared to day seven (169.3 ± 1.6mm), and 2.23 m/s (ICC=0.49) day one (174.1 ± 2.8mm), compared to day seven (170.8 ± 2.2mm). Running represented fair to good reliability, 2.23 m/s (ICC=.67) day one (167.8 ± 2.5mm), compared to day seven (166.13 ± 1.6mm), 2.68 m/s (ICC=.51) day one (167.8 ± 2.9mm), compared to day seven (163.6 ± 1.9mm), and 3.12 m/s (ICC=.74) day one (166.2 ± 2.5mm), compared to day seven (164.6 ± 1.9mm).

The drop of the navicular represented poor to fair reliability across different speeds. Walking represented poor to fair reliability, 1.34 m/s (ICC=0.51) day one (7.4 ± 0.83mm), compared to day seven (5.9 ± 0.9) mm, 1.79 m/s (ICC=0.11) day one (9.5 ± 1.6) mm, compared to day seven (9.31 ± 1.35mm), and 2.23 m/s (ICC=0.05) day one (8.9 ± 1.4mm), compared to day seven (7.9 ± 1.3mm). Running represented poor to fair reliability, 2.23 m/s (ICC=0.56) day one (15.2 ± 1.5mm), compared to day seven (12.6 ± 1.2mm), 2.68 m/s (ICC=0.13) day one (15.2 ± 1.7mm), compared to day seven (15 ± 1.4mm), and 3.12 m/s (ICC= .32) day one (16.7 ± 1.5mm), compared to day seven (14.1 ± 1.8mm).

CHAPTER 4

DISCUSSION

The purpose of this study is to see if navicular drop is influenced by mode or speed of locomotion, if it is will there be other influences such as position of the forefoot and heel soft tissue, and will those factors influence those measures. The secondary purpose of this study is to see if the static and dynamic measures of navicular drop will be reliable.

The hypothesis that mode and speed of locomotion will affect navicular position and drop is supported by the results of the study. The results show that during running the vertical height of the navicular was lower to the ground, and the drop of the navicular was greater compared to walking. During the dynamic movement the vertical height of the navicular was lower to the ground, and the drop of the navicular was highest in medium speed compared to high and low speed.

The hypothesis that navicular drop during dynamic movement is influenced by the change of the fat pads around the toe and heel under different conditions were supported by the results of the study. The drop of the triangle was higher in running compared to walking. During running the mean measure of navicular drop measured by the triangle was (7.6 ± 0.4mm), and walking (4.3 ± 0.3mm). During running and walking the mean absolute measure of navicular drop was (14.83 ± 0.61mm) and walking was (8.19 ± 0.52mm). From the results of the study, there was a difference between the triangle and absolute height measures. The results suggest that there is fat pad compression around the great toe and heel affecting the measure of navicular drop. The deformation of the fat pads is in agreement with previous research. (De Clercq et al., 1994; Qian et al., 2010) The vertical movement of the great toe and heel were lower to

the ground during running as compared to walking. The vertical height of the great toe and heel were lower in medium speed compared to low and high speeds.

The hypothesis that static and dynamic measures were reliable measures is supported by some of the results of the study. The static measure of navicular drop represented poor reliability (ICC=0.21). The results were lower compared to previous research conducted by Picciano and colleagues where the observed the navicular drop test to have good reliability (ICC=0.61). (Picciano et al., 1993) Placing the subtalar joint in the neutral position could have attributed to the poor reliability of this study, which is supported by previous research. (Picciano et al., 1993)

The results of the current study suggest that navicular drop is greater during running compared to walking. The amount of drop change from walking to running might also be influenced by the amount of pressure induced by running, or the compression of the fat pads around the heel and great toe. This can be described by the change in navicular drop from the measurement of the absolute height, to the measure of drop within the triangle. Dynamic measure of navicular drop is greater than the static measure of navicular drop. When doing dynamic movements, more movement of the navicular bone and foot is expected then what is measured statically.

Some limitations of the study include testing of some of the participants were not at the same time of the day 7 days later. Testing at different times could affect foot structure and mobility, and the participant could be fatigued, but the relative changes were seen, and this would not affect the direction of movement so this did not affect our results. The study only looked at recreationally active individuals, athletes may have better technique and greater muscle strength in the foot; this is a hypothesis that needs to

be tested. Skin reflective markers may not represent the most accurate movement of the actual bony structure; the markers could be influenced by inversion of the foot, or skin movement. There is not a lot of soft tissue around the foot structures; the reflective markers did not affect our results.

Future studies need to be conducted on how the compression of soft tissue may affect navicular drop. Future studies need to study how musculature in the arch may affect navicular drop, and to compare muscle strength and thickness to the measurement of navicular drop. Future studies need to study if there is a better, more reliable way to measure navicular drop to get a more accurate measure when dynamic movements are preformed.

Navicular drop is greater in running compared to walking. Navicular drop is greater during dynamic movement when compared to a static measurement. Results suggest that when conducting static measures of navicular drop more structures incorporating the calcaneus and toe would be appropriate.

REFERENCES

Brody, D. M. (1982). Techniques in the evaluation and treatment of the injured runner. *Orthop Clin North Am, 13*(3), 541-558.
Brown, C. N., & Mynark, R. (2007). Balance deficits in recreational athletes with chronic ankle instability. *J Athl Train, 42*(3), 367-373.
Cohen, S. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd. ed.). London ; New York: Routledge.
De Clercq, D., Aerts, P., & Kunnen, M. (1994). The mechanical characteristics of the human heel pad during foot strike in running: an in vivo cineradiographic study. *J Biomech, 27*(10), 1213-1222.
Egloff M, H., H. (2015). Comparison of Manual and Digital Measurement of the Navicular Drop in Two Different Procedures. *Physiotherapy, 101*.
Eichelberger, J. G. (2015). Reliability of a New Foot Model for Dynamic Navicular Drop Measurement *Physiotherapy, 101*, 346.
Eslami, M., Damavandi, M., & Ferber, R. (2014). Association of navicular drop and selected lower-limb biomechanical measures during the stance phase of running. *J Appl Biomech, 30*(2), 250-254. doi: 10.1123/jab.2011-0162
Lippincott, Williams, D. G., & Wilkins. (2014). ACSM GUidelines for Exercise Testing and Prescription. *61*(3), 8-43. doi: 10.1016/j.biopsych.2006.04.007
Loudon, J. K., Jenkins, W., & Loudon, K. L. (1996). The relationship between static posture and ACL injury in female athletes. *J Orthop Sports Phys Ther, 24*(2), 91-97. doi: 10.2519/jospt.1996.24.2.91
McPoil, T. G., & Cornwall, M. W. (1996). The relationship between static lower extremity measurements and rearfoot motion during walking. *J Orthop Sports Phys Ther, 24*(5), 309-314. doi: 10.2519/jospt.1996.24.5.309
McPoil, T. G., Cornwall, M. W., Medoff, L., Vicenzino, B., Forsberg, K., & Hilz, D. (2008). Arch height change during sit-to-stand: an alternative for the navicular drop test. *J Foot Ankle Res, 1*(1), 3. doi: 10.1186/1757-1146-1-3
Nielsen, R. G., Rathleff, M. S., Simonsen, O. H., & Langberg, H. (2009). Determination of normal values for navicular drop during walking: a new model correcting for foot length and gender. *J Foot Ankle Res, 2*, 12. doi: 10.1186/1757-1146-2-12
Picciano, A. M., Rowlands, M. S., & Worrell, T. (1993). Reliability of open and closed kinetic chain subtalar joint neutral positions and navicular drop test. *J Orthop Sports Phys Ther, 18*(4), 553-558. doi: 10.2519/jospt.1993.18.4.553
Qian, Z., Ren, L., & Ren, L. (2010). A Coupling Analysis of the Biomechanical Functions of Human Foot Complex during Locomotion. *Journal of Bionic Engineering, 4*, 150-157.

APPENDIX A

DATA OUTPUT

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  /METHOD=SSTYPE(3)
  /CRITERIA=ALPHA(.05)
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General Linear Model

Notes

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	N of Rows in Working Data File	28
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
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	Elapsed Time	00:00:00.09

[DataSet2]

Within-Subjects Factors

Measure: MEASURE_1

Mode	Velocity	Dependent Variable
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	2	W2
	3	W3
2	1	R1
	2	R2
	3	R3

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Mode	Pillai's Trace	.779	95.157[b]	1.000	27.000	.000
	Wilks' Lambda	.221	95.157[b]	1.000	27.000	.000
	Hotelling's Trace	3.524	95.157[b]	1.000	27.000	.000
	Roy's Largest Root	3.524	95.157[b]	1.000	27.000	.000
Velocity	Pillai's Trace	.281	5.069[b]	2.000	26.000	.014
	Wilks' Lambda	.719	5.069[b]	2.000	26.000	.014
	Hotelling's Trace	.390	5.069[b]	2.000	26.000	.014
	Roy's Largest Root	.390	5.069[b]	2.000	26.000	.014
Mode * Velocity	Pillai's Trace	.123	1.826[b]	2.000	26.000	.181
	Wilks' Lambda	.877	1.826[b]	2.000	26.000	.181
	Hotelling's Trace	.140	1.826[b]	2.000	26.000	.181
	Roy's Largest Root	.140	1.826[b]	2.000	26.000	.181

a. Design: Intercept

Within Subjects Design: Mode + Velocity + Mode * Velocity

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser		
Mode	1.000	.000	0	.	1.000		
Velocity	.927	1.974	2	.373	.932		
Mode * Velocity	.917	2.266	2	.322	.923		

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon Huynh-Feldt	Epsilon Lower-bound
Mode	1.000	1.000
Velocity	.998	.500
Mode * Velocity	.988	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Mode + Velocity + Mode * Velocity

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	
Mode	Sphericity Assumed	1853.783	1	1853.783	95.157	
	Greenhouse-Geisser	1853.783	1.000	1853.783	95.157	
	Huynh-Feldt	1853.783	1.000	1853.783	95.157	
	Lower-bound	1853.783	1.000	1853.783	95.157	
Error(Mode)	Sphericity Assumed	525.994	27	19.481		
	Greenhouse-Geisser	525.994	27.000	19.481		
	Huynh-Feldt	525.994	27.000	19.481		
	Lower-bound	525.994	27.000	19.481		
Velocity	Sphericity Assumed	124.181	2	62.091	5.610	
	Greenhouse-Geisser	124.181	1.864	66.631	5.610	

	Huynh-Feldt	124.181	1.996	62.200	5.610	
	Lower-bound	124.181	1.000	124.181	5.610	
Error(Velocity)	Sphericity Assumed	597.644	54	11.067		
	Greenhouse-Geisser	597.644	50.320	11.877		
	Huynh-Feldt	597.644	53.905	11.087		
	Lower-bound	597.644	27.000	22.135		
Mode * Velocity	Sphericity Assumed	19.448	2	9.724	1.746	
	Greenhouse-Geisser	19.448	1.846	10.536	1.746	
	Huynh-Feldt	19.448	1.975	9.846	1.746	
	Lower-bound	19.448	1.000	19.448	1.746	
Error(Mode*Velocity)	Sphericity Assumed	300.809	54	5.571		
	Greenhouse-Geisser	300.809	49.840	6.036		
	Huynh-Feldt	300.809	53.332	5.640		
	Lower-bound	300.809	27.000	11.141		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.
Mode	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000
	Lower-bound	.000
Error(Mode)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Velocity	Sphericity Assumed	.006
	Greenhouse-Geisser	.007
	Huynh-Feldt	.006
	Lower-bound	.025
Error(Velocity)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Mode * Velocity	Sphericity Assumed	.184
	Greenhouse-Geisser	.187
	Huynh-Feldt	.185
	Lower-bound	.198
Error(Mode*Velocity)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Mode	Velocity	Type III Sum of Squares	df	Mean Square	F	
Mode	Linear		1853.783	1	1853.783	95.157	
Error(Mode)	Linear		525.994	27	19.481		
Velocity		Linear	74.548	1	74.548	8.483	
		Quadratic	49.633	1	49.633	3.719	
Error(Velocity)		Linear	237.278	27	8.788		
		Quadratic	360.366	27	13.347		
Mode * Velocity	Linear	Linear	.422	1	.422	.083	
		Quadratic	19.027	1	19.027	3.138	
Error(Mode*Velocity)	Linear	Linear	137.082	27	5.077		
		Quadratic	163.727	27	6.064		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Mode	Velocity	Sig.
Mode	Linear		.000
Error(Mode)	Linear		
Velocity		Linear	.007
		Quadratic	.064
Error(Velocity)		Linear	
		Quadratic	
Mode * Velocity	Linear	Linear	.775
		Quadratic	.088

Error(Mode*Velocity)	Linear	Linear	
		Quadratic	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	4818892.966	1	4818892.966	12288.090	.000
Error	10588.310	27	392.160		

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  /READNAMES=on
  /ASSUMEDSTRWIDTH=32767.
EXECUTE.
DATASET NAME DataSet3 WINDOW=FRONT.
DATASET ACTIVATE DataSet3.
DATASET CLOSE DataSet2.
GLM W1 W2 W3 R1 R2 R3
  /WSFACTOR=Mode 2 Polynomial Velocity 3 Polynomial
  /MEASURE=Drop
  /METHOD=SSTYPE(3)
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Mode Velocity Mode*Velocity.
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General Linear Model

Notes

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	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		GLM W1 W2 W3 R1 R2 R3 /WSFACTOR=Mode 2 Polynomial Velocity 3 Polynomial /MEASURE=Drop /METHOD=SSTYPE(3) /CRITERIA=ALPHA(.05) /WSDESIGN=Mode Velocity Mode*Velocity.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.02

Within-Subjects Factors

Measure: Drop

Mode	Velocity	Dependent Variable
1	1	W1
	2	W2
	3	W3
2	1	R1
	2	R2
	3	R3

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Mode	Pillai's Trace	.779	95.157[b]	1.000	27.000	.000
	Wilks' Lambda	.221	95.157[b]	1.000	27.000	.000
	Hotelling's Trace	3.524	95.157[b]	1.000	27.000	.000
	Roy's Largest Root	3.524	95.157[b]	1.000	27.000	.000
Velocity	Pillai's Trace	.281	5.069[b]	2.000	26.000	.014
	Wilks' Lambda	.719	5.069[b]	2.000	26.000	.014
	Hotelling's Trace	.390	5.069[b]	2.000	26.000	.014
	Roy's Largest Root	.390	5.069[b]	2.000	26.000	.014
Mode * Velocity	Pillai's Trace	.123	1.826[b]	2.000	26.000	.181
	Wilks' Lambda	.877	1.826[b]	2.000	26.000	.181
	Hotelling's Trace	.140	1.826[b]	2.000	26.000	.181
	Roy's Largest Root	.140	1.826[b]	2.000	26.000	.181

a. Design: Intercept

Within Subjects Design: Mode + Velocity + Mode * Velocity

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: Drop

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser		
Mode	1.000	.000	0	.	1.000		
Velocity	.927	1.974	2	.373	.932		
Mode * Velocity	.917	2.266	2	.322	.923		

Mauchly's Test of Sphericity[a]

Measure: Drop

Within Subjects Effect	Epsilon Huynh-Feldt	Epsilon Lower-bound
Mode	1.000	1.000
Velocity	.998	.500
Mode * Velocity	.988	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Mode + Velocity + Mode * Velocity

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: Drop

Source		Type III Sum of Squares	df	Mean Square	F	
Mode	Sphericity Assumed	1853.783	1	1853.783	95.157	
	Greenhouse-Geisser	1853.783	1.000	1853.783	95.157	
	Huynh-Feldt	1853.783	1.000	1853.783	95.157	
	Lower-bound	1853.783	1.000	1853.783	95.157	
Error(Mode)	Sphericity Assumed	525.994	27	19.481		
	Greenhouse-Geisser	525.994	27.000	19.481		
	Huynh-Feldt	525.994	27.000	19.481		

	Lower-bound	525.994	27.000	19.481		
Velocity	Sphericity Assumed	124.181	2	62.091	5.610	
	Greenhouse-Geisser	124.181	1.864	66.631	5.610	
	Huynh-Feldt	124.181	1.996	62.200	5.610	
	Lower-bound	124.181	1.000	124.181	5.610	
Error(Velocity)	Sphericity Assumed	597.644	54	11.067		
	Greenhouse-Geisser	597.644	50.320	11.877		
	Huynh-Feldt	597.644	53.905	11.087		
	Lower-bound	597.644	27.000	22.135		
Mode * Velocity	Sphericity Assumed	19.448	2	9.724	1.746	
	Greenhouse-Geisser	19.448	1.846	10.536	1.746	
	Huynh-Feldt	19.448	1.975	9.846	1.746	
	Lower-bound	19.448	1.000	19.448	1.746	
Error(Mode*Velocity)	Sphericity Assumed	300.809	54	5.571		
	Greenhouse-Geisser	300.809	49.840	6.036		
	Huynh-Feldt	300.809	53.332	5.640		
	Lower-bound	300.809	27.000	11.141		

Tests of Within-Subjects Effects

Measure: Drop

Source		Sig.
Mode	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000

	Lower-bound	.000
Error(Mode)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Velocity	Sphericity Assumed	.006
	Greenhouse-Geisser	.007
	Huynh-Feldt	.006
	Lower-bound	.025
Error(Velocity)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Mode * Velocity	Sphericity Assumed	.184
	Greenhouse-Geisser	.187
	Huynh-Feldt	.185
	Lower-bound	.198
Error(Mode*Velocity)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: Drop

Source	Mode	Velocity	Type III Sum of Squares	df	Mean Square	F	
Mode	Linear		1853.783	1	1853.783	95.157	
Error(Mode)	Linear		525.994	27	19.481		
Velocity		Linear	74.548	1	74.548	8.483	
		Quadratic	49.633	1	49.633	3.719	
Error(Velocity)		Linear	237.278	27	8.788		
		Quadratic	360.366	27	13.347		
Mode * Velocity	Linear	Linear	.422	1	.422	.083	
		Quadratic	19.027	1	19.027	3.138	
Error(Mode*Velocity)	Linear	Linear	137.082	27	5.077		
		Quadratic	163.727	27	6.064		

Tests of Within-Subjects Contrasts

Measure: Drop

Source	Mode	Velocity	Sig.
Mode	Linear		.000
Error(Mode)	Linear		
Velocity		Linear	.007
		Quadratic	.064

Error(Velocity)		Linear	
		Quadratic	
Mode * Velocity	Linear	Linear	.775
		Quadratic	.088
Error(Mode*Velocity)	Linear	Linear	
		Quadratic	

Tests of Between-Subjects Effects

Measure: Drop

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	22248.110	1	22248.110	205.781	.000
Error	2919.115	27	108.115		

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  /READNAMES=on
  /ASSUMEDSTRWIDTH=32767.
EXECUTE.
DATASET NAME DataSet2 WINDOW=FRONT.
DATASET ACTIVATE DataSet2.
DATASET CLOSE DataSet1.
GLM W1 W2 W3 R1 R2 R3
  /WSFACTOR=Mode 2 Polynomial Velocity 3 Polynomial
  /MEASURE=THDrop
  /METHOD=SSTYPE(3)
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Mode Velocity Mode*Velocity.
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General Linear Model

Notes

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Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		GLM W1 W2 W3 R1 R2 R3 /WSFACTOR=Mode 2 Polynomial Velocity 3 Polynomial /MEASURE=THDrop /METHOD=SSTYPE(3) /CRITERIA=ALPHA(.05) /WSDESIGN=Mode Velocity Mode*Velocity.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.02

Within-Subjects Factors

Measure: THDrop

Mode	Velocity	Dependent Variable
1	1	W1
	2	W2
	3	W3
2	1	R1
	2	R2
	3	R3

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Mode	Pillai's Trace	.859	164.641[b]	1.000	27.000	.000
	Wilks' Lambda	.141	164.641[b]	1.000	27.000	.000
	Hotelling's Trace	6.098	164.641[b]	1.000	27.000	.000
	Roy's Largest Root	6.098	164.641[b]	1.000	27.000	.000
Velocity	Pillai's Trace	.118	1.737[b]	2.000	26.000	.196
	Wilks' Lambda	.882	1.737[b]	2.000	26.000	.196
	Hotelling's Trace	.134	1.737[b]	2.000	26.000	.196
	Roy's Largest Root	.134	1.737[b]	2.000	26.000	.196
Mode * Velocity	Pillai's Trace	.229	3.860[b]	2.000	26.000	.034
	Wilks' Lambda	.771	3.860[b]	2.000	26.000	.034
	Hotelling's Trace	.297	3.860[b]	2.000	26.000	.034
	Roy's Largest Root	.297	3.860[b]	2.000	26.000	.034

a. Design: Intercept
 Within Subjects Design: Mode + Velocity + Mode * Velocity
b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: THDrop

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser		
Mode	1.000	.000	0	.	1.000		
Velocity	.914	2.339	2	.311	.921		
Mode * Velocity	.860	3.925	2	.141	.877		

Mauchly's Test of Sphericity[a]

Measure: THDrop

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Mode	1.000	1.000
Velocity	.985	.500
Mode * Velocity	.933	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Mode + Velocity + Mode * Velocity

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: THDrop

Source		Type III Sum of Squares	df	Mean Square	F	
Mode	Sphericity Assumed	477.222	1	477.222	164.641	
	Greenhouse-Geisser	477.222	1.000	477.222	164.641	
	Huynh-Feldt	477.222	1.000	477.222	164.641	
	Lower-bound	477.222	1.000	477.222	164.641	
Error(Mode)	Sphericity Assumed	78.261	27	2.899		
	Greenhouse-Geisser	78.261	27.000	2.899		
	Huynh-Feldt	78.261	27.000	2.899		
	Lower-bound	78.261	27.000	2.899		

Velocity	Sphericity Assumed	2.825	2	1.412	1.923	
	Greenhouse-Geisser	2.825	1.842	1.534	1.923	
	Huynh-Feldt	2.825	1.970	1.434	1.923	
	Lower-bound	2.825	1.000	2.825	1.923	
Error(Velocity)	Sphericity Assumed	39.671	54	.735		
	Greenhouse-Geisser	39.671	49.723	.798		
	Huynh-Feldt	39.671	53.192	.746		
	Lower-bound	39.671	27.000	1.469		
Mode * Velocity	Sphericity Assumed	5.722	2	2.861	2.588	
	Greenhouse-Geisser	5.722	1.754	3.262	2.588	
	Huynh-Feldt	5.722	1.866	3.066	2.588	
	Lower-bound	5.722	1.000	5.722	2.588	
Error(Mode*Velocity)	Sphericity Assumed	59.692	54	1.105		
	Greenhouse-Geisser	59.692	47.364	1.260		
	Huynh-Feldt	59.692	50.392	1.185		
	Lower-bound	59.692	27.000	2.211		

Tests of Within-Subjects Effects

Measure: THDrop

Source		Sig.
Mode	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000
	Lower-bound	.000

Error(Mode)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Velocity	Sphericity Assumed	.156
	Greenhouse-Geisser	.160
	Huynh-Feldt	.157
	Lower-bound	.177
Error(Velocity)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Mode * Velocity	Sphericity Assumed	.084
	Greenhouse-Geisser	.092
	Huynh-Feldt	.089
	Lower-bound	.119
Error(Mode*Velocity)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: THDrop

Source	Mode	Velocity	Type III Sum of Squares	df	Mean Square	F	
Mode	Linear		477.222	1	477.222	164.641	
Error(Mode)	Linear		78.261	27	2.899		
Velocity		Linear	2.819	1	2.819	3.293	
		Quadratic	.006	1	.006	.010	
Error(Velocity)		Linear	23.113	27	.856		
		Quadratic	16.557	27	.613		
Mode * Velocity	Linear	Linear	.978	1	.978	.656	
		Quadratic	4.744	1	4.744	6.590	
Error(Mode*Velocity)	Linear	Linear	40.257	27	1.491		
		Quadratic	19.436	27	.720		

Tests of Within-Subjects Contrasts

Measure: THDrop

Source	Mode	Velocity	Sig.
Mode	Linear		.000
Error(Mode)	Linear		
Velocity		Linear	.081
		Quadratic	.922
Error(Velocity)		Linear	
		Quadratic	
Mode * Velocity	Linear	Linear	.425
		Quadratic	.016
Error(Mode*Velocity)	Linear	Linear	
		Quadratic	

Tests of Between-Subjects Effects

Measure: THDrop

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	6166.178	1	6166.178	279.358	.000
Error	595.962	27	22.073		

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  /CELLRANGE=full
  /READNAMES=on
  /ASSUMEDSTRWIDTH=32767.
EXECUTE.
DATASET NAME DataSet1 WINDOW=FRONT.
GLM W1 W2 W3 R1 R2 R3
  /WSFACTOR=Mode 2 Polynomial Velocity 3 Polynomial
  /MEASURE=HeelY
  /METHOD=SSTYPE(3)
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Mode Velocity Mode*Velocity.
```

General Linear Model

Notes

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	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		GLM W1 W2 W3 R1 R2 R3 /WSFACTOR=Mode 2 Polynomial Velocity 3 Polynomial /MEASURE=HeelY /METHOD=SSTYPE(3) /CRITERIA=ALPHA(.05) /WSDESIGN=Mode Velocity Mode*Velocity.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.03

Within-Subjects Factors

Measure: HeelY

Mode	Velocity	Dependent Variable
1	1	W1
	2	W2
	3	W3
2	1	R1
	2	R2
	3	R3

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Mode	Pillai's Trace	.189	6.273[b]	1.000	27.000	.019
	Wilks' Lambda	.811	6.273[b]	1.000	27.000	.019
	Hotelling's Trace	.232	6.273[b]	1.000	27.000	.019
	Roy's Largest Root	.232	6.273[b]	1.000	27.000	.019
Velocity	Pillai's Trace	.237	4.046[b]	2.000	26.000	.030
	Wilks' Lambda	.763	4.046[b]	2.000	26.000	.030
	Hotelling's Trace	.311	4.046[b]	2.000	26.000	.030
	Roy's Largest Root	.311	4.046[b]	2.000	26.000	.030
Mode * Velocity	Pillai's Trace	.082	1.156[b]	2.000	26.000	.330
	Wilks' Lambda	.918	1.156[b]	2.000	26.000	.330
	Hotelling's Trace	.089	1.156[b]	2.000	26.000	.330
	Roy's Largest Root	.089	1.156[b]	2.000	26.000	.330

a. Design: Intercept

Within Subjects Design: Mode + Velocity + Mode * Velocity

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: HeelY

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser		
Mode	1.000	.000	0	.	1.000		
Velocity	.918	2.215	2	.330	.924		
Mode * Velocity	.744	7.684	2	.021	.796		

Mauchly's Test of Sphericity[a]

Measure: HeelY

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound

Mode	1.000	1.000
Velocity	.989	.500
Mode * Velocity	.838	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Mode + Velocity + Mode * Velocity

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: HeelY

Source		Type III Sum of Squares	df	Mean Square	F	
Mode	Sphericity Assumed	115.547	1	115.547	6.273	
	Greenhouse-Geisser	115.547	1.000	115.547	6.273	
	Huynh-Feldt	115.547	1.000	115.547	6.273	
	Lower-bound	115.547	1.000	115.547	6.273	
Error(Mode)	Sphericity Assumed	497.358	27	18.421		
	Greenhouse-Geisser	497.358	27.000	18.421		
	Huynh-Feldt	497.358	27.000	18.421		
	Lower-bound	497.358	27.000	18.421		
Velocity	Sphericity Assumed	76.814	2	38.407	3.574	
	Greenhouse-Geisser	76.814	1.849	41.544	3.574	
	Huynh-Feldt	76.814	1.979	38.816	3.574	
	Lower-bound	76.814	1.000	76.814	3.574	

Error(Velocity)	Sphericity Assumed	580.346	54	10.747		
	Greenhouse-Geisser	580.346	49.923	11.625		
	Huynh-Feldt	580.346	53.431	10.862		
	Lower-bound	580.346	27.000	21.494		
Mode * Velocity	Sphericity Assumed	11.619	2	5.810	.738	
	Greenhouse-Geisser	11.619	1.593	7.296	.738	
	Huynh-Feldt	11.619	1.676	6.931	.738	
	Lower-bound	11.619	1.000	11.619	.738	
Error(Mode*Velocity)	Sphericity Assumed	425.190	54	7.874		
	Greenhouse-Geisser	425.190	42.998	9.888		
	Huynh-Feldt	425.190	45.261	9.394		
	Lower-bound	425.190	27.000	15.748		

Tests of Within-Subjects Effects

Measure: HeelY

Source		Sig.
Mode	Sphericity Assumed	.019
	Greenhouse-Geisser	.019
	Huynh-Feldt	.019
	Lower-bound	.019
Error(Mode)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Velocity	Sphericity Assumed	.035

	Greenhouse-Geisser	.039
	Huynh-Feldt	.035
	Lower-bound	.069
Error(Velocity)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Mode * Velocity	Sphericity Assumed	.483
	Greenhouse-Geisser	.455
	Huynh-Feldt	.461
	Lower-bound	.398
Error(Mode*Velocity)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: HeelY

Source	Mode	Velocity	Type III Sum of Squares	df	Mean Square	F	
Mode	Linear		115.547	1	115.547	6.273	
Error(Mode)	Linear		497.358	27	18.421		
Velocity		Linear	47.780	1	47.780	6.223	
		Quadratic	29.034	1	29.034	2.101	
Error(Velocity)		Linear	207.301	27	7.678		
		Quadratic	373.044	27	13.816		

Mode * Velocity	Linear	Linear	10.688	1	10.688	1.265	
		Quadratic	.931	1	.931	.128	
Error(Mode*Velocity)	Linear	Linear	228.120	27	8.449		
		Quadratic	197.069	27	7.299		

Tests of Within-Subjects Contrasts

Measure: HeelY

Source	Mode	Velocity	Sig.
Mode	Linear		.019
Error(Mode)	Linear		
Velocity		Linear	.019
		Quadratic	.159
Error(Velocity)		Linear	
		Quadratic	
Mode * Velocity	Linear	Linear	.271
		Quadratic	.724
Error(Mode*Velocity)	Linear	Linear	
		Quadratic	

Tests of Between-Subjects Effects

Measure: HeelY

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	4215824.826	1	4215824.826	19862.976	.000

Error	5730.625	27	212.245		

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  /READNAMES=on
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/MEASURE=ToeY

/METHOD=SSTYPE(3)

/CRITERIA=ALPHA(.05)

/WSDESIGN=Mode Velocity Mode*Velocity.

General Linear Model

Notes

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	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		GLM W1 W2 W3 R1 R2 R3 /WSFACTOR=Mode 2 Polynomial Velocity 3 Polynomial /MEASURE=ToeY /METHOD=SSTYPE(3) /CRITERIA=ALPHA(.05) /WSDESIGN=Mode Velocity Mode*Velocity.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.02

Within-Subjects Factors

Measure: ToeY

Mode	Velocity	Dependent Variable
1	1	W1
	2	W2
	3	W3
2	1	R1
	2	R2
	3	R3

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Mode	Pillai's Trace	.692	60.598[b]	1.000	27.000	.000
	Wilks' Lambda	.308	60.598[b]	1.000	27.000	.000
	Hotelling's Trace	2.244	60.598[b]	1.000	27.000	.000
	Roy's Largest Root	2.244	60.598[b]	1.000	27.000	.000
Velocity	Pillai's Trace	.228	3.836[b]	2.000	26.000	.035
	Wilks' Lambda	.772	3.836[b]	2.000	26.000	.035

	Hotelling's Trace	.295	3.836[b]	2.000	26.000	.035
	Roy's Largest Root	.295	3.836[b]	2.000	26.000	.035
Mode * Velocity	Pillai's Trace	.083	1.179[b]	2.000	26.000	.324
	Wilks' Lambda	.917	1.179[b]	2.000	26.000	.324
	Hotelling's Trace	.091	1.179[b]	2.000	26.000	.324
	Roy's Largest Root	.091	1.179[b]	2.000	26.000	.324

a. Design: Intercept
Within Subjects Design: Mode + Velocity + Mode * Velocity
b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: ToeY

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser		
Mode	1.000	.000	0	.	1.000		
Velocity	.926	1.995	2	.369	.931		
Mode * Velocity	.830	4.846	2	.089	.855		

Mauchly's Test of Sphericity[a]

Measure: ToeY

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Mode	1.000	1.000
Velocity	.997	.500
Mode * Velocity	.907	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Mode + Velocity + Mode * Velocity

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: ToeY

Source		Type III Sum of Squares	df	Mean Square	F	
Mode	Sphericity Assumed	1003.057	1	1003.057	60.598	
	Greenhouse-Geisser	1003.057	1.000	1003.057	60.598	
	Huynh-Feldt	1003.057	1.000	1003.057	60.598	
	Lower-bound	1003.057	1.000	1003.057	60.598	
Error(Mode)	Sphericity Assumed	446.920	27	16.553		
	Greenhouse-Geisser	446.920	27.000	16.553		
	Huynh-Feldt	446.920	27.000	16.553		
	Lower-bound	446.920	27.000	16.553		
Velocity	Sphericity Assumed	122.032	2	61.016	4.747	
	Greenhouse-Geisser	122.032	1.862	65.523	4.747	
	Huynh-Feldt	122.032	1.995	61.171	4.747	
	Lower-bound	122.032	1.000	122.032	4.747	
Error(Velocity)	Sphericity Assumed	694.024	54	12.852		
	Greenhouse-Geisser	694.024	50.285	13.802		
	Huynh-Feldt	694.024	53.863	12.885		

	Lower-bound	694.024	27.000	25.705		
Mode * Velocity	Sphericity Assumed	27.171	2	13.586	1.703	
	Greenhouse-Geisser	27.171	1.709	15.896	1.703	
	Huynh-Feldt	27.171	1.813	14.984	1.703	
	Lower-bound	27.171	1.000	27.171	1.703	
Error(Mode*Velocity)	Sphericity Assumed	430.843	54	7.979		
	Greenhouse-Geisser	430.843	46.152	9.335		
	Huynh-Feldt	430.843	48.961	8.800		
	Lower-bound	430.843	27.000	15.957		

Tests of Within-Subjects Effects

Measure: ToeY

Source		Sig.
Mode	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000
	Lower-bound	.000
Error(Mode)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	

	Lower-bound	
Velocity	Sphericity Assumed	.013
	Greenhouse-Geisser	.015
	Huynh-Feldt	.013
	Lower-bound	.038
Error(Velocity)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Mode * Velocity	Sphericity Assumed	.192
	Greenhouse-Geisser	.197
	Huynh-Feldt	.195
	Lower-bound	.203
Error(Mode*Velocity)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: ToeY

Source	Mode	Velocity	Type III Sum of Squares	df	Mean Square	F	
Mode	Linear		1003.057	1	1003.057	60.598	
Error(Mode)	Linear		446.920	27	16.553		
Velocity		Linear	48.974	1	48.974	4.742	
		Quadratic	73.058	1	73.058	4.751	

Error(Velocity)		Linear	278.836	27	10.327		
		Quadratic	415.188	27	15.377		
Mode * Velocity	Linear	Linear	15.592	1	15.592	2.004	
		Quadratic	11.580	1	11.580	1.416	
Error(Mode*Velocity)	Linear	Linear	210.094	27	7.781		
		Quadratic	220.749	27	8.176		

Tests of Within-Subjects Contrasts

Measure: ToeY

Source	Mode	Velocity	Sig.
Mode	Linear		.000
Error(Mode)	Linear		
Velocity		Linear	.038
		Quadratic	.038
Error(Velocity)		Linear	

		Quadratic	
Mode * Velocity	Linear	Linear	.168
		Quadratic	.244
Error(Mode*Velocity)	Linear	Linear	
		Quadratic	

Tests of Between-Subjects Effects

Measure: ToeY

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	3705254.546	1	3705254.546	16906.013	.000
Error	5917.532	27	219.168		

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ers\jmutchle
r\Downloads\
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final.xlsx'

/SHEET=name
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/CELLRANGE=f
ull

/READNAMES=o
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n

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WINDOW=FRONT
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/SUMMARY=MEA
NS CORR

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Reliability

Notes

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		missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=NPST_1 NPST_2 /SCALE('ALL VARIABLES') ALL /MODEL=ALPHA /SUMMARY=MEANS CORR /ICC=MODEL(RANDOM) TYPE(CONSISTENCY) CIN=95 TESTVAL=0.
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	Elapsed Time	00:00:00.00

[DataSet1]

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	14	100.0
	Excluded[a]	0	0.0
	Total	14	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.688	.692	2

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	180.871	178.706	183.036	4.330	1.024	9.373	2
Inter-Item Correlations	.529	.529	.529	0.000	1.000	0.000	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.524[a]	.014	.818	3.204	13	13	.022
Average Measures	.688	.028	.900	3.204	13	13	.022

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the

```
RELIABILITY

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Prel_1
NPrel_2

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VARIABLES')
ALL

/MODEL=ALPHA

/SUMMARY=MEA
NS CORR

/ICC=MODEL(R
ANDOM)
TYPE(CONSIST
ENCY) CIN=95
TESTVAL=0.
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Reliability

Notes

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Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=NPrel_1 NPrel_2 /SCALE('ALL VARIABLES') ALL /MODEL=ALPHA /SUMMARY=MEANS CORR /ICC=MODEL(RANDOM) TYPE(CONSISTENCY) CIN=95 TESTVAL=0.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	14	100.0
	Excluded[a]	0	0.0
	Total	14	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items

.743	.757	2

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	175.440	173.623	177.257	3.634	1.021	6.604	2
Inter-Item Correlations	.609	.609	.609	0.000	1.000	0.000	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.591[a]	.110	.847	3.887	13	13	.010
Average Measures	.743	.199	.917	3.887	13	13	.010

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the

```
RELIABILITY

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Drop_1
NDrop_2

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VARIABLES')
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/MODEL=ALPHA

/SUMMARY=MEA
NS CORR

/ICC=MODEL(R
ANDOM)
TYPE(CONSIST
ENCY) CIN=95
TESTVAL=0.
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Reliability

Notes

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Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=NDrop_1 NDrop_2 /SCALE('ALL VARIABLES') ALL /MODEL=ALPHA /SUMMARY=MEANS CORR /ICC=MODEL(RANDOM) TYPE(CONSISTENCY) CIN=95 TESTVAL=0.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	14	100.0
	Excluded[a]	0	0.0
	Total	14	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.351	.360	2

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	5.431	5.084	5.779	.695	1.137	.242	2
Inter-Item Correlations	.219	.219	.219	0.000	1.000	0.000	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.213[a]	-.338	.655	1.541	13	13	.223
Average Measures	.351	-1.021	.792	1.541	13	13	.223

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	14	100.0
	Excluded[a]	0	0.0
	Total	14	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.728	.738	2

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	174.185	172.769	175.600	2.830	1.016	4.005	2
Inter-Item Correlations	.584	.584	.584	0.000	1.000	0.000	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.572[a]	.083	.839	3.677	13	13	.013
Average Measures	.728	.153	.913	3.677	13	13	.013

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the

```
RELIABILITY

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/SUMMARY=MEA
NS CORR

/ICC=MODEL(R
ANDOM)
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ENCY) CIN=95
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Reliability

Notes

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	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=NPV4_1 NPV4_2 /SCALE('ALL VARIABLES') ALL /MODEL=ALPHA /SUMMARY=MEANS CORR /ICC=MODEL(RANDOM) TYPE(CONSISTENCY) CIN=95 TESTVAL=0.

Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	14	100.0
	Excluded[a]	0	0.0
	Total	14	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.682	.733	2

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	171.440	169.324	173.557	4.232	1.025	8.956	2
Inter-Item Correlations	.578	.578	.578	0.000	1.000	0.000	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.517[a]	.004	.815	3.142	13	13	.024
Average Measures	.682	.009	.898	3.142	13	13	.024

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the

```
RELIABILITY

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PV5w_1
NPV5w_2

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VARIABLES')
ALL

/MODEL=ALPHA

/STATISTICS=
DESCRIPTIVE

/SUMMARY=MEA
NS CORR

/ICC=MODEL(R
ANDOM)
TYPE(CONSIST
ENCY) CIN=95
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Reliability

Notes

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Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.

	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=NPV5w_1 NPV5w_2 /SCALE('ALL VARIABLES') ALL /MODEL=ALPHA /STATISTICS=DESCRIPTIVE /SUMMARY=MEANS CORR /ICC=MODEL(RANDOM) TYPE(CONSISTENCY) CIN=95 TESTVAL=0.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	14	100.0
	Excluded[a]	0	0.0
	Total	14	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.656	.670	2

Item Statistics

	Mean	Std. Deviation	N

NPV5w_1	174.09027321	10.561681312	14
NPV5w_2	170.76989421	8.199393096	14

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	172.430	170.770	174.090	3.320	1.019	5.512	2
Inter-Item Correlations	.504	.504	.504	0.000	1.000	0.000	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.488[a]	-.034	.801	2.907	13	13	.032
Average Measures	.656	-.071	.890	2.907	13	13	.032

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the

```
RELIABILITY

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NPV5r_2

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VARIABLES')
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/STATISTICS=
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/SUMMARY=MEA
NS CORR

/ICC=MODEL(R
ANDOM)
TYPE(CONSIST
ENCY) CIN=95
TESTVAL=0.
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Reliability

Notes

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	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=NPV5r_1 NPV5r_2 /SCALE('ALL VARIABLES') ALL /MODEL=ALPHA /STATISTICS=DESCRIPTIVE /SUMMARY=MEANS CORR /ICC=MODEL(RANDOM) TYPE(CONSISTENCY) CIN=95 TESTVAL=0.
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	Elapsed Time	00:00:00.00

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	14	100.0
	Excluded[a]	0	0.0
	Total	14	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.800	.844	2

Item Statistics

	Mean	Std. Deviation	N
NPV5r_1	167.75319457	9.407375355	14
NPV5r_2	166.13127350	6.089257707	14

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	166.942	166.131	167.753	1.622	1.010	1.315	2
Inter-Item Correlations	.731	.731	.731	0.000	1.000	0.000	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.667[a]	.232	.879	4.999	13	13	.003
Average Measures	.800	.377	.936	4.999	13	13	.003

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the

```
RELIABILITY

/VARIABLES=N
PV6_1 NPV6_2

/SCALE('ALL
VARIABLES')
ALL

/MODEL=ALPHA

/STATISTICS=
DESCRIPTIVE

/SUMMARY=MEA
NS CORR

/ICC=MODEL(R
ANDOM)
TYPE(CONSIST
ENCY) CIN=95
TESTVAL=0.
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Reliability

Notes

Output Created		09-MAR-2017 13:10:13
Comments		
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	Weight	<none>
	Split File	<none>

	N of Rows in Working Data File Matrix Input	14
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=NPV6_1 NPV6_2 /SCALE('ALL VARIABLES') ALL /MODEL=ALPHA /STATISTICS=DESCRIPTIVE /SUMMARY=MEANS CORR /ICC=MODEL(RANDOM) TYPE(CONSISTENCY) CIN=95 TESTVAL=0.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	14	100.0
	Excluded[a]	0	0.0
	Total	14	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.672	.712	2

Item Statistics

	Mean	Std. Deviation	N
NPV6_1	167.84799079	10.694085879	14
NPV6_2	163.64924621	6.991911477	14

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	165.749	163.649	167.848	4.199	1.026	8.815	2
Inter-Item Correlations	.553	.553	.553	0.000	1.000	0.000	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.506[a]	-.010	.810	3.051	13	13	.027
Average Measures	.672	-.021	.895	3.051	13	13	.027

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the

```
RELIABILITY

/VARIABLES=N
PV7_1 NPV7_2

/SCALE('ALL
VARIABLES')
ALL

/MODEL=ALPHA

/STATISTICS=
DESCRIPTIVE

/SUMMARY=MEA
NS CORR

/ICC=MODEL(R
ANDOM)
TYPE(CONSIST
ENCY) CIN=95
TESTVAL=0.
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Reliability

Notes

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	N of Rows in Working Data File Matrix Input	14
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=NPV7_1 NPV7_2 /SCALE('ALL VARIABLES') ALL /MODEL=ALPHA /STATISTICS=DESCRIPTIVE /SUMMARY=MEANS CORR /ICC=MODEL(RANDOM) TYPE(CONSISTENCY) CIN=95 TESTVAL=0.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	14	100.0
	Excluded[a]	0	0.0
	Total	14	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.849	.868	2

Item Statistics

	Mean	Std. Deviation	N
NPV7_1	166.23646321	9.514107747	14
NPV7_2	164.63004850	7.179566030	14

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	165.433	164.630	166.236	1.606	1.010	1.290	2
Inter-Item Correlations	.767	.767	.767	0.000	1.000	0.000	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.738[a]	.360	.907	6.620	13	13	.001
Average Measures	.849	.529	.952	6.620	13	13	.001

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the

```
RELIABILITY

/VARIABLES=N
PV3Dr_1
NPV3Dr_2

/SCALE('ALL
VARIABLES')
ALL

/MODEL=ALPHA

/STATISTICS=
DESCRIPTIVE

/SUMMARY=MEA
NS CORR

/ICC=MODEL(R
ANDOM)
TYPE(CONSIST
ENCY) CIN=95
TESTVAL=0.
```

Reliability

Notes

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Comments		
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	Split File	<none>

	N of Rows in Working Data File Matrix Input	14
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=NPV3Dr_1 NPV3Dr_2 /SCALE('ALL VARIABLES') ALL /MODEL=ALPHA /STATISTICS=DESCRIPTIVE /SUMMARY=MEANS CORR /ICC=MODEL(RANDOM) TYPE(CONSISTENCY) CIN=95 TESTVAL=0.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	14	100.0
	Excluded[a]	0	0.0
	Total	14	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.671	.674	2

Item Statistics

	Mean	Std. Deviation	N
NPV3Dr_1	7.436211857142850	3.122417805801380	14
NPV3Dr_2	5.936715285714290	3.510705018250180	14

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	6.686	5.937	7.436	1.499	1.253	1.124	2
Inter-Item Correlations	.509	.509	.509	0.000	1.000	0.000	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.505[a]	-.012	.809	3.042	13	13	.027
Average Measures	.671	-.024	.894	3.042	13	13	.027

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the

```
RELIABILITY

/VARIABLES=N
PV4Dr_1
NPV4Dr_2

/SCALE('ALL
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ALL

/MODEL=ALPHA

/STATISTICS=
DESCRIPTIVE

/SUMMARY=MEA
NS CORR

/ICC=MODEL(R
ANDOM)
TYPE(CONSIST
ENCY) CIN=95
TESTVAL=0.
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Reliability

Notes

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Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=NPV4Dr_1 NPV4Dr_2 /SCALE('ALL VARIABLES') ALL /MODEL=ALPHA /STATISTICS=DESCRIPTIVE /SUMMARY=MEANS CORR /ICC=MODEL(RANDOM) TYPE(CONSISTENCY) CIN=95 TESTVAL=0.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	14	100.0
	Excluded[a]	0	0.0
	Total	14	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.200	.201	2

Item Statistics

	Mean	Std. Deviation	N
NPV4Dr_1	9.479237142857140	5.762728471638790	14
NPV4Dr_2	9.381933071428580	5.095445200211980	14

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	9.431	9.382	9.479	.097	1.010	.005	2
Inter-Item Correlations	.112	.112	.112	0.000	1.000	0.000	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig

Single Measures	.111[a]	-.427	.591	1.250	13	13	.347
Average Measures	.200	-1.492	.743	1.250	13	13	.347

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the

```
RELIABILITY

/VARIABLES=N
PV5wDr_1
NPV5wDr_2

/SCALE('ALL
VARIABLES')
ALL

/MODEL=ALPHA

/STATISTICS=
DESCRIPTIVE

/SUMMARY=MEA
NS CORR

/ICC=MODEL(R
ANDOM)
TYPE(CONSIST
ENCY) CIN=95
TESTVAL=0.
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Reliability

Notes

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	Weight	<none>
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Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=NPV5wDr_1 NPV5wDr_2 /SCALE('ALL VARIABLES') ALL /MODEL=ALPHA /STATISTICS=DESCRIPTIVE /SUMMARY=MEANS CORR /ICC=MODEL(RANDOM) TYPE(CONSISTENCY) CIN=95 TESTVAL=0.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	14	100.0
	Excluded[a]	0	0.0
	Total	14	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha[a]	Cronbach's Alpha Based on Standardized Items[a]	N of Items
-.095	-.095	2

a. The value is negative due to a negative average covariance among items. This violates reliability model assumptions. You may want to check item codings.

Item Statistics

	Mean	Std. Deviation	N
NPV5wDr_1	8.945469857142850	5.076077973850330	14
NPV5wDr_2	7.936300071428570	5.040655976793490	14

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	8.441	7.936	8.945	1.009	1.127	.509	2
Inter-Item Correlations	-.045	-.045	-.045	0.000	1.000	0.000	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig

Single Measures	-.045[a]	-.546	.480	.913	13	13	.564
Average Measures	-.095	-2.410	.649	.913	13	13	.564

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the

```
RELIABILITY

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PV5rDr_1
NPV5rDr_2

/SCALE('ALL
VARIABLES')
ALL

/MODEL=ALPHA

/STATISTICS=
DESCRIPTIVE

/SUMMARY=MEA
NS CORR

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ANDOM)
TYPE(CONSIST
ENCY) CIN=95
TESTVAL=0.
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Reliability

Notes

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Comments			
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Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=NPV5rDr_1 NPV5rDr_2 /SCALE('ALL VARIABLES') ALL /MODEL=ALPHA /STATISTICS=DESCRIPTIVE /SUMMARY=MEANS CORR /ICC=MODEL(RANDOM) TYPE(CONSISTENCY) CIN=95 TESTVAL=0.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.00

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	14	100.0
	Excluded[a]	0	0.0
	Total	14	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.716	.722	2

Item Statistics

	Mean	Std. Deviation	N
NPV5rDr_1	15.282544785714300	5.360128821103480	14
NPV5rDr_2	12.574920785714300	4.554354172362840	14

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	13.929	12.575	15.283	2.708	1.215	3.666	2
Inter-Item Correlations	.565	.565	.565	0.000	1.000	0.000	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig

Single Measures	.558[a]	.062	.833	3.524	13	13	.015
Average Measures	.716	.116	.909	3.524	13	13	.015

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the

```
RELIABILITY

/VARIABLES=N
PV6Dr_1
NPV6Dr_2

/SCALE('ALL
VARIABLES')
ALL

/MODEL=ALPHA

/STATISTICS=
DESCRIPTIVE

/SUMMARY=MEA
NS CORR

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ANDOM)
TYPE(CONSIST
ENCY) CIN=95
TESTVAL=0.
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Reliability

Notes

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Comments			
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Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=NPV6Dr_1 NPV6Dr_2 /SCALE('ALL VARIABLES') ALL /MODEL=ALPHA /STATISTICS=DESCRIPTIVE /SUMMARY=MEANS CORR /ICC=MODEL(RANDOM) TYPE(CONSISTENCY) CIN=95 TESTVAL=0.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	14	100.0
	Excluded[a]	0	0.0
	Total	14	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.225	.228	2

Item Statistics

	Mean	Std. Deviation	N
NPV6Dr_1	15.187757071428600	6.196778654327880	14
NPV6Dr_2	15.056948071428600	5.325138047302570	14

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	15.122	15.057	15.188	.131	1.009	.009	2
Inter-Item Correlations	.129	.129	.129	0.000	1.000	0.000	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.127[a]	-.414	.602	1.291	13	13	.326

Average Measures	.225	-1.413	.751	1.291	13	13	.326

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the

```
RELIABILITY

/VARIABLES=N
PV7Dr_1
NPV7Dr_2

/SCALE('ALL
VARIABLES')
ALL

/MODEL=ALPHA

/STATISTICS=
DESCRIPTIVE

/SUMMARY=MEA
NS CORR

/ICC=MODEL(R
ANDOM)
TYPE(CONSIST
ENCY) CIN=95
TESTVAL=0.
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Reliability

Notes

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Comments		
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	N of Rows in Working Data File Matrix Input	14
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=NPV7Dr_1 NPV7Dr_2 /SCALE('ALL VARIABLES') ALL /MODEL=ALPHA /STATISTICS=DESCRIPTIVE /SUMMARY=MEANS CORR /ICC=MODEL(RANDOM) TYPE(CONSISTENCY) CIN=95 TESTVAL=0.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	14	100.0
	Excluded[a]	0	0.0
	Total	14	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.483	.491	2

Item Statistics

	Mean	Std. Deviation	N
NPV7Dr_1	16.799279500000000	5.519212261478760	14
NPV7Dr_2	14.076145785714300	6.729956760040360	14

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	15.438	14.076	16.799	2.723	1.193	3.708	2
Inter-Item Correlations	.325	.325	.325	0.000	1.000	0.000	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.319[a]	-.233	.716	1.936	13	13	.123

Average Measures	.483	-.609	.834	1.936	13	13	.123

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the

APPENDIX B

IRB APPROVAL

Joshua Krispin, ATC, LAT- Graduate Student/Principal Investigator
Li Li, PhD- Georgia Southern University Research Member/ Advisor (Chair)

The purpose of this study is to discover a more reliable way to measure navicular drop, and to determine if a static measure of navicular drop correlates to the same measure in a dynamic state

Research Questions:

1. Can the static measure of the navicular drop test be more reliable?
2. Does the static measure of navicular drop correlate in a dynamic setting while walking in running?

Hypothesis:

1. The static measure of the navicular drop test can me made more reliable
2. Static and dynamic measure of navicular drop will correlate

Literature Review.

The rationale for taking static clinical measurements of the lower extremity and foot is to determine abnormalities, which could affect foot motion during walking.[1] The logic for this rationale is the hypothesis that structure dictates function.[1] In order to understand functional occurrences during gait, one must measure static relationships in the lower extremity.[1]

The measure of navicular drop has been used as an indicator of pronation of the foot.[2] It is defined as the distance in which the navicular tuberosity moves in standing, as the subtalar joint is allowed to move from its neutral position to a relaxed position.[2] The subtalar joint is made up of the articulation of the talus and the calcaneus.[3] In running, over pronation occurs in about 10% of cases, and may result in running related overuse injuries.[4] Shin splints or medial tibial stress syndrome occurs in 7-20% of the population in runners, and accounts for 5% of athletic injuries.[4,5] The typical range for navicular drop is between 5-9mm.[6] Values less than 4mm represents a high arch, and values greater than 10mm represents a low arch.[6,7] Navicular drop measurements greater than 9mm are associated with shin splints, and measurements greater than 13mm predisposes people for anterior cruciate ligament injuries.[8] The navicular drop test has been used as a clinical method to assess foot mobility and pronation.[9,10]

Brody stated that the navicular drop test is performed with the patient standing on a firm surface with the navicular tuberosity palpated and marked with ink bilaterally.[6] The patient's subtalar joint was placed into neutral, where the talar head could be palpated on the medial and lateral side of the joint.[6,10] The height of the navicular tuberosity to the floor is marked on an index card.[6,10] The patient is then instructed to

relax both feet resulting in a lower position of the navicular tuberosity, and then the height of the navicular tuberosity was marked on the index card.[6,10] To determine the measure of navicular drop Brody stated the height of the navicular bone in subtalar neutral is subtracted from the height of the navicular tuberosity in a relaxed position.[6] Picciano and colleagues (1993) measured reliability of the navicular drop, and found intra-tester interclass correlations (ICC) of .61-.79, and an inter-tester ICC value of .57 which are poor values[11] In the study of Loudon and colleagues (1996) measured ICC values for intra-tester navicular drop and received an ICC value of .76.[10] Reasons for the low reliability of the OKC and CKC of subtalar joint neutral may be attributed to inexperienced testers, and difficulty of coming to an accurate bisection of the talar joint.[11] For it to be a more reliable clinical measure, clinicians will need to practice the measurements to become more experienced, which will result in better reliability.[11]

In a study conducted by Eslami and colleagues (2014), 16 men with no history of injury were recruited.[12] Nine reflective markers were placed over the right foot and tibia.[12] Ten running trials were performed bearfoot and the subjects ran at a cadence of 170 steps per minute controlled by a metronome.[12]

In a study conducted from Nielsen and colleagues (2009), 280 participants volunteered, and were only included if they had no lower extremity deformities, major trauma, and no pain in the lower extremity in the last three months. [13] The participants were instructed to walk barefoot on a treadmill at a self-selected pace, and twenty consecutive steps were recorded for analysis.[13] A 2D motion capture system was used to measure navicular drop during walking, which consisted of a digital camera with a 12 mm lens sampling at 86 Hz.[13]

If the static measure of navicular drop can predict lower extremity dysfunction[8,14], few studies to date have directly looked at the correlation of the static measure of navicualr drop to a dynamic measure.

Outcome.

The results we expect to achieve are that the navicular drop test can be made a more reliable clinical test. We also expect to find that the static measure of navicular drop should correlate to a dynamic measure while walking and running at different speeds.

Describe your subjects.

There will be 15 recreationally active college aged participants.

Inclusion Criteria:

- No apparent neuromuscular pathology
- College aged non-athlete
- Did not participate as a participant in the pilot study of this project

Exclusion Criteria:

- History of lower extremity injury in the past 6 months
- History of lower extremity surgery

- Participant in the pilot study of this project
- Answered yes to any question on the Physical Activity Readiness Questionnaire

Recruitment and Incentives:

Participants will participate in the study voluntarily; there will be no reward or compensation upon completion. The participants will be recruited by a verbal presentation in the health and kinesiology classes at Georgia Southern University.

Research Procedures and Timeline:

The study will include 15 college aged 18-35 year old healthy individuals. The participants will be barefoot for this study. The navicular drop test will be performed on every right foot for all of the participants. A black ink marker will be used to mark out the navicular tuberosity. The primary investigator will put the patient into subtalar neutral, and mark a line on the index card. The participant will then be asked to relax and another mark will be placed on the index card. After those two measures the participants navicular drop will be calculated. Then three reflective markers will be placed on the participants' foot over the 1st metatarsal joint, the navicular tuberosity, and the calcaneus. After the markers are placed on the skin, the participant will be instructed to walk on the treadmill barefoot at 3,4,5 MPH. Since gait stabilizes in about 20 seconds after walking, the participant will walk for 20 seconds, and collect the data for 10 seconds. The participant will walk about 30 seconds for each trial. After the walking trial is completed, the running trial will start where the participant will run at 5,6,7 MPH. The same time will apply as they did for walking, they will run for about 30 seconds for each trial. There will be a one minute rest period between each trial to try and prevent fatigue. The approximate time to collect the data for this study will take approximately 45 minutes. The participants will be asked to come back in 4-5 days to repeat the study to calculate the reliability for the measures.

Data Analysis:

The data will be collected, and will be input into a computer where it will be coded to protect the identity of that participant. Statistical Package for Social Sciences Software (SPSS) version 21.0 will be used to analyze the data that is collected. A Pearson correlation is going to be conducted to see if the static measure and dynamic measure of navicular drop correlate to one another. Interclass correlation coefficients will also be conducted to determine the reliability values with the measurement of navicular drop.

Special Conditions:

Risk.

In this study, risk is no greater than risk associated with daily life experiences. On the treadmill there is a stop cord that can be pulled to stop the treadmill at anytime the

participant cannot complete the speed requirement. The participants will not be pushed into fatigue since they will only be walking and running for 30 seconds each trial with a minute break in between each trial.

Research involving minors.

This research study will not involve minors

Deception.

This study does not involve deception

Medical procedures.

This study does not involve medical procedures

Literature Review Reference list (not counted in page limit):

1. McPoil TG, Cornwall MW. The relationship between static lower extremity measurements and rearfoot motion during walking. *J Orthop Sports Phys Ther.* 1996;24(5):309-314.
2. Mueller MJ, Host JV, Norton BJ. Navicular drop as a composite measure of excessive pronation. *Journal of the American Podiatric Medical Association.* 1993;83(4):198-202.
3. Seeley RV, C. Regan, J. Russo, A. *Seeley's Anatomy & Physiology.* New York, NY: McGraw Hill Companies; 2008.
4. Taunton JE, Ryan MB, Clement DB, McKenzie DC, Lloyd-Smith DR, Zumbo BD. A retrospective case-control analysis of 2002 running injuries. *British journal of sports medicine.* 2002;36(2):95-101.
5. Yates B, Allen MJ, Barnes MR. Outcome of surgical treatment of medial tibial stress syndrome. *The Journal of bone and joint surgery. American volume.* 2003;85-A(10):1974-1980.
6. Brody DM. Techniques in the evaluation and treatment of the injured runner. *The Orthopedic clinics of North America.* 1982;13(3):541-558.
7. Michelson JD, DM. McFarland, E. Injury Risk Associated with Pes Planus in Athletes. *Foot Ankle Int.* 2003;23(7):629-633.
8. Beckett ME, Massie DL, Bowers KD, Stoll DA. Incidence of Hyperpronation in the ACL Injured Knee: A Clinical Perspective. *J Athl Train.* 1992;27(1):58-62.
9. McPoil TG, Cornwall MW, Medoff L, Vicenzino B, Forsberg K, Hilz D. Arch height change during sit-to-stand: an alternative for the navicular drop test. *J Foot Ankle Res.* 2008;1(1):3.
10. Loudon JK, Jenkins W, Loudon KL. The relationship between static posture and ACL injury in female athletes. *The Journal of orthopaedic and sports physical therapy.* 1996;24(2):91-97.

11. Picciano AM, Rowlands MS, Worrell T. Reliability of open and closed kinetic chain subtalar joint neutral positions and navicular drop test. *The Journal of orthopaedic and sports physical therapy.* 1993;18(4):553-558.
12. Eslami M, Damavandi M, Ferber R. Association of navicular drop and selected lower-limb biomechanical measures during the stance phase of running. *J Appl Biomech.* 2014;30(2):250-254.
13. Nielsen RG, Rathleff MS, Simonsen OH, Langberg H. Determination of normal values for navicular drop during walking: a new model correcting for foot length and gender. *Journal of foot and ankle research.* 2009;2:12.
14. Delacerda FG. A study of anatomical factors involved in shinsplints. *J Orthop Sports Phys Ther.* 1980;2(2):55-59.

Reminder: No research can be undertaken until your proposal has been approved by the IRB.

INFORMED CONSENT

CONSENT TO ACT AS A SUBJECT IN AN EXPERIMENTAL STUDY

Title of Project: The Reliability of the Navicular Drop Test and its Transferability to a Dynamic Measure

Investigator's Name: Joshua Krispin, ATC, LAT Phone: (419)-705-5151

Participants Name:______________________________ Date:______________

Data Collection will be in the Biomechanics Laboratory, Georgia Southern University

We are attempting to make the navicular drop test a more reliable clinical test for foot pronation. We are also attempting to see if the static measure of navicular drop will correlate to a dynamic measure of navicular drop. The results of this study will help medical professionals better understand, diagnose, and treat over pronation injuries in the recreational and athletic population.

You are invited to participate in this study because you have met the qualification criteria for this study. Further you have no history of lower extremity surgery, you have answered "no" to all of the questions on the Physical Activity Readiness Questionnaire (PAR-Q), and have had no lower extremity injury in the last 6 months.

If you agree to participate in the study you will be asked to attend testing sessions that will last approximately 45 minutes. You will be asked to return to participate in the same study within a 4-5 day time period. During the session, your foot will be placed into different positions to perform the navicular drop test. Three reflective adhesive markers will be applied to the inside of your right foot. During the session you will be asked to walk on a treadmill at 3,4,5 MPH and run on a treadmill at 5,6,7 MPH with bare feet. We will record your running and walking trials with a video camera to be later analyzed.

The data that we collect will be analyzed in a software program; no one will be able to tell that it is you the video will be confidential.

The risk of this study is no greater than the risk associated with daily life expectations. There is minimal risk of physical injury during this session. Appropriate rest will be given between each trial to allow for rest. You understand that medical care is available if needed, but neither financial compensation nor free medical treatment is provided. You are not waving any rights that you may have against the University for injury resulting in negligence. Should medical attention be required contact Health Services at (912) 478-5641.

You will not receive any direct benefit from participating in this study.

You will attend two testing sessions, and after the first is completed you will attend another session in 4-5 days.

You understand that you will not receive compensation for you participation in this project, and you will not be responsible for any costs.

You understand that you do not have to participate in this project and your decision is voluntarily. At any time you can choose not to participate by telling the primary investigator. You can terminate participation in this study without any prejudice to future care.

All the data concerning yourself will be kept confidential. You understand that any information about your records will be handled confidentially. A case number will indicate your identity on all records. You will not be mentioned in any publications. Your records will be kept for a period of 3 years after the completion of this study as required by the Georgia Board of Regents policy.

You understand that you can decline to answer specific questions

You understand that there is no deception involved with this project

You certify that you are 18 years of age or older, and you have read the preceding information, or it has been read to you, and understand its contents. If you have any questions regarding this research can be answered by the investigator listed at the beginning of this consent form. Or you can call the Office of Research Integrity for answers to questions at (912) 478-5465.

You have been provided a copy of this form. The Project has been reviewed and approved by the GSU Institutional Review Board under the tracking number H16372.

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APPENDIX C

REVIEW OF LITERATURE

The foot is root between the body and the earth.(Chan & Rudins, 1994) The foot is an intricate mechanism that cushions the body, and can adapt to uneven surfaces.(Chan & Rudins, 1994) The foot also applies traction for movement, and awareness of joint and body position for balance.(Chan & Rudins, 1994) The rationale for taking static clinical measurements of the lower extremity and foot is to determine abnormalities, which could affect foot motion during walking.(McPoil & Cornwall, 1996) The logic for this rationale is the hypothesis that structure dictates function.(McPoil & Cornwall, 1996) In order to understand functional occurrences during gait, one must measure static relationships in the lower extremity.(McPoil & Cornwall, 1996) It can be hypothesized that static measurements can predict dynamic movement of the lower extremity and the foot during walking.(McPoil & Cornwall, 1996)

Definition

The measure of navicular drop has been used as an indicator of pronation of the foot.(Mueller, Host, & Norton, 1993) It is defined as the distance in which the navicular tuberosity moves in standing, as the subtalar joint is allowed to move from its neutral position to a relaxed position.(Mueller et al., 1993) The subtalar joint is made up of the articulation of the talus and the calcaneus.(Seeley, 2008) The subtalar joint is a single axis joint with triplanar motions that occur in all thee cardinal planes. (McPoil & Knecht, 1985) Subtalar joint neutral is the position where neither pronation nor supination occurs in the foot and arches in regards to the talus. (Kirby, 2000) The arches of the foot provide an elastic, springy connection between the forefoot and hindfoot.(Franco, 1987) The arch

demonstrates two extremes of anatomical structure pes cavus and pes planus. (Franco, 1987)

Epidemiology

In running, over pronation occurs in about 10% of cases, and may result in running related overuse injuries.(Taunton et al., 2002) Shin splints or medial tibial stress syndrome occurs in 7-20% of the population in runners, and accounts for 5% of athletic injuries.(Taunton et al., 2002; Yates, Allen, & Barnes, 2003) The typical range for navicular drop is between 5-9mm.(Brody, 1982) Values less than 4mm represents a high arch, and values greater than 10mm represents a low arch.(Brody, 1982; Michelson, 2003) Navicular drop measurements greater than 9mm are associated with shin splints, and measurements greater than 13mm predisposes people for anterior cruciate ligament injuries.(Beckett, Massie, Bowers, & Stoll, 1992) Navicular drop explains 28-38% of the variability for measures of tibial internal rotation, peak knee adduction, and peak ankle inversion.(Eslami et al., 2014)

Anatomy

The human foot is a unique structure formed with over 100 muscles, tendons, and ligaments, 26 bones, and 33 joints. (Rolian, Lieberman, & Hallgrimsson, 2010; Wright, Ivanenko, & Gurfinkel, 2012) The unusual shape of the bones and ligaments and lesser muscular support forms three strong arches: the transverse, lateral, and medial longitudinal arches.(Chan & Rudins, 1994; Franco, 1987; Wright et al., 2012) Of the twenty-six bones in the foot, there are fourteen phalangeal bones, five metatarsal bones, and seven tarsal bones, along with two sesamoid bones beneath the first

metatarsal.(Seeley, 2008) The seven tarsal bones consist of the calcaneus, talus, cuboid, navicular, medial cuneiform, intermediate cuneiform, and lateral cuneiform.(Seeley, 2008) The talus is the ankle bone, which articulates with the tibia and fibula which forms the ankle joint.(Seeley, 2008) The talus also articulates with the calcaneus and the navicular bones.(Seeley, 2008) The calcaneus or the heel bone is the strongest and largest bone in the foot.(Seeley, 2008) The navicular is a boat shaped bone, which lies posteriorly to the talus and anterior to the cuneiforms.(Seeley, 2008) The metatarsal bones and phalanges of the foot are arranged in a similar manner to the hand.(Seeley, 2008) The foot has a convex shape dorsally, and is concave ventrally to form three major arches in the foot.(Seeley, 2008)

The three major arches are the medial longitudinal arch, the lateral longitudinal arch, and the transverse arch.(Seeley, 2008) The arches distribute the weight of the body between the heel and the ball of the foot during standing and walking.(Seeley, 2008) Weight is distributed to the calcaneus then through the arches along the lateral side to the ball of the foot.(Seeley, 2008) The shape of the arches is maintained by the configuration of the bones, ligaments and muscles acting on the foot.(Seeley, 2008) The ligaments of the arches serve two functions, to hold the bones in their proper alignment as segments of the arch, and to provide ties across the arch.(Seeley, 2008) The medial longitudinal arch is composed of six bones, the three cuneiforms, the talus, the calcaneus, and the navicular serving as the keystone of the arch.(Franco, 1987) The medial longitudinal arch is reinforced by the tibialis anterior and posterior muscles, which pull the medial boarder of the foot upward.(Franco, 1987) As people bear weight through their arches, some of the ligaments become stretched, giving the foot more flexibility allowing it to adjust to

uneven surfaces.(Seeley, 2008) Failure to absorb weight and arch formation is called pes planus or flat feet, where the medial longitudinal arch is depressed or collapsed.(Seeley, 2008) Flat feet may occur when the muscles and ligaments supporting the arch fatigue and allow the arch to collapse.(Seeley, 2008) During prolonged standing, the plantar calcaneonavicular ligament is the main support for the medial longitudinal arch.(Seeley, 2008) The calcaneonavicular ligament extends from the calcaneus to the navicular, which may stretch, flattening the medial longitudinal and transverse arch.(Seeley, 2008)

Arch Dysfunction

A functional relationship exists between the structure of the arch of the foot and the biomechanics of the lower leg.(Franco, 1987) Muscular imbalances, structural alignments of joints, pronation of the foot, and gait abnormalities are caused by either pes cavus (High arch) or pes planus (flat foot).(Franco, 1987) The extremely high arched foot of pes cavus, weight bearing is distributed unevenly along the metatarsal heads along the lateral boarder of the foot.(Franco, 1987) To identify pes cavus, the patient should be non-weight bearing.(Franco, 1987) If the forefoot is lower than the heel, but the arch depresses when weight bearing, the condition is known as flexible pes cavus.(Franco, 1987) If the arch still remains high when the person is weight bearing, the condition will be known as rigid pes cavus.(Subotnick, 1980) With the poor shock absorption, feet with either flexible or rigid pes cavus are prone to heel pain and stress fractures.(Franco, 1987; Subotnick, 1980)

Opposite of pes cavus is pes planus, and this is where the head of the talus is displaced medially and plantarward from the navicular.(Franco, 1987) This stretches the calcaneonavicular ligament and the tendon of the tibialis posterior muscle, which results

in the loss of the medial longitudinal arch.(Hoppenfeld, 1976) If the medial longitudinal arch is absent in both non-weight bearing and weight bearing positions, the patient has rigid flatfoot. If the medial longitudinal arch is present when the patient is sitting or standing on the toes, but it disappears during foot flat stance, the patient has supple flatfoot.(Hoppenfeld, 1976) The flattening of the medial longitudinal arch disrupts the normal process of weight bearing; many people with pes planus demonstrated a flat-footed gait with no toe-off.(Franco, 1987) Symptoms of pes planus include a pronated foot, shortening of the peroneal muscles, and laxity of the supporting structures of the medial side of the foot. (Cooper, 1979) The structural changes that accompany flat arched feet, affect normal biomechanics of the lower extremity.(Franco, 1987) Pronation which is a normal necessity of gait, becomes exaggerated in the foot with pes planus.(Franco, 1987) The lack of an arch maintains the foot in a flexible position, hinders normal gait, and creates compensatory pronation disorders. (Franco, 1987)

Biomechanics of the foot

From a biomechanical viewpoint, the foot is typically considered as a functional unit with two important aims: to support the body weight (static) and to serve as a lever to propel the body forward in walking and running (dynamic).(Bramble & Lieberman, 2004; Ker, Bennett, Bibby, Kester, & Alexander, 1987) None of the bones between the calcaneus and the heads of the metatarsals transmit weight directly to the ground.(Chan & Rudins, 1994) The weight on the talus is transmitted to the calcaneus in the rear and to the heads of the metatarsals in the front.(Chan & Rudins, 1994) The arches of the foot provide elastic, springy connection between the forefoot and hind foot to absorb and distribute the body weight during locomotion. (Franco, 1987) During movement, the

subtalar joint can move in three planes simultaneously, also called triplanar movements. (Hunter S, 2000) These triplanar motions are called pronation and supination, and can be described in both the open kinetic chain (OKC) (Non-weight-bearing position), and the closed kinetic chain (CKC) (Wight-bearing position).(Picciano et al., 1993) The three planes that the motions occur in are the sagittal plane (dorsiflexion and plantarflexion), frontal plane (inversion and eversion), and transverse plane (adduction and internal rotation).(Chan & Rudins, 1994; Hunter S, 2000) The mechanical axes of the foot and ankle are not perpendicular to any of the cardinal planes, so all motion is triplanar and in some cases uniaxial.(Chan & Rudins, 1994) The terms supination of the foot is a rotation which results in inversion, adduction, and plantar flexion; while pronation of the foot results in eversion, abduction, and dorsiflexion.(Chan & Rudins, 1994)

Gait

Throughout history, people have taken interest in the finite movements in walking.(Whittle, 1996) In the Renaissance time period notable individuals such as Leonardo da Vinci, Galileo, Newton and Borelli tired to understand the rudiments of biomechanics.(Whittle, 1996) Advancing through history to the early nineteenth century, the Weber brothers out Germany were first to formally investigate biomechanics.(Whittle, 1996) From the advancements in the Renaissance time period through the nineteenth century, four different areas of science have contributed to the development of gait analysis.(Whittle, 1996) The four different areas of gait are kinematics, kinetics, electromyography and engineering mathematics.(Whittle, 1996) Gait analysis was a foreign concept in the clinic until about 1970's when suitable systems for gait analysis were made available for routine use.(Whittle, 1996) Jaquelin Perry,

David Sutherland, Jim Gage, and Gordon Rose all orthopedic surgeons were responsible for the introduction of gait analysis for routine patient care.(Whittle, 1996)

Walking Gait

The human body is a well-balanced walking machine that has a stable and energy-efficient gait through sophisticated mechanics that are not easily replicable.(Mummolo, Mangialardi, & Kim, 2013) A gait cycle is the period of time between two identical events in the walking process during which the lower body performs two strides for each leg.(Mummolo et al., 2013) Stride length is the distance between two heel contacts, and step length is the distance between the two feet at the beginning and end of a step during the gait cycle in walking.(Mummolo et al., 2013) The gait cycle is divided into the stance and swing phases.(Mayich, Novak, Vena, Daniels, & Brodsky, 2014) The stance phase comprises approximately 60% of each cycle, while the swing phases accounts for roughly 40%.(Mayich et al., 2014) The stance phase is were people bear the most weight while the lower extremity and pelvis rotate over the fixed foot.(Mayich et al., 2014) As the body continues it's motion and the foot starts to leave the ground to enter swing phase, the anterior hip and leg muscles act to flex the hip propelling the foot into swing phase.(Mayich et al., 2014) In the stance phase the foot progresses into three "rocker" periods that start with heel strike and ends with toe off.(Mayich et al., 2014) The first rocker period consists of the eccentric contraction of the ankle dorsiflexors to allow the ankle to plantar flex in a controlled manner.(Mayich et al., 2014) In the second rocker period the tibia rolls forward over the ankle to continue forward body movement.(Mayich et al., 2014) In The third rocker period, the foot is dorsiflexed through the ankle and the metatarsophalangeal joints, which culminates in to

toe-off.(Mayich et al., 2014)

Motion at the level of individual joints in the foot during gait has been difficult to study.(Mayich et al., 2014) With this difficulty the role of motion at different joints during stance phase of gait is not fully understood.(Mayich et al., 2014) This difficulty is due impart the variation that is observed in the anatomy of the foot due to adaptations of multiple joints in the foot.(Daniels & Thomas, 2008; Davis, 1997) This has been demonstrated in post-ankle fusion gait.(Mayich et al., 2014) The gait cycle progresses through 3 rockers and does not rely on the tibiotalar motion for foot motion.(Mayich et al., 2014) The talonavicular, subtalar, and calcaneocuboid as well as proximal joints can adapt for gait.(Daniels & Thomas, 2008) Individuals with a painful foot or ankle will avoid weight bearing on that affected side, which can create the antalgic or altered gait.(Mayich et al., 2014) Individuals with deconditioned or weakened muscles and altered foot mechanics will have spent more time in stance phase.(Mayich et al., 2014)

Analyzing gait is important in assessing abnormality and functional issues after treatment of several foot and ankle conditions.(Beischer, Brodsky, Pollo, & Peereboom, 1999; Brodsky, Baum, Pollo, & Mehta, 2007) Tracking markers can be placed on the skin over palpable landmarks to allow the measurement of one segment of the body of interest.(Leardini et al., 2007) Attaching markers on the skin of the foot over palpable landmarks has limitations, skin can have significant error with skin moving as much as 16.4 mm over the navicular and 12.1 mm over the calcaneus at toe-off.(Shultz, Kedgley, & Jenkyn, 2011) Error has also been recognized in reliably in marking the anatomical structure.(Carson, Harrington, Thompson, O'Connor, & Theologis, 2001) Despite these shortcomings, and given the nature of the invasive nature of fixation of markers, skin-

mounted markers are the acceptable marker arrangement at this time.(Mayich et al., 2014) The analysis of the walking pattern is important in a treatment and rehabilitation context as well as prevention of injury for the active population.(Mohammed, 2016)

Running Gait

Running has grown in popularity over the years, and so does the interest in the research and assessment of running gait.(Higginson, 2009) Whether the purpose of running is to catch the bus or win a race, the biomechanics are similar.(Chan & Rudins, 1994) Speed, anatomic variations, state of training, fatigue, footwear, and running surfaces all influence biomechanical variables.(Williams, 1985) Basic understanding of the biomechanics of running is important when dealing with a wide variety of lower extremity injuries.(Chan & Rudins, 1994) Advancements in technology used in the analysis of running gait are making this capability more widely available to a broader range of professionals.(Higginson, 2009) The increase in the number or recreational runners has had obvious implications to professionals such as clinicians, physical therapists, and who ever offer services to the evaluation and rehabilitation of the running related injuries.(Higginson, 2009)

Treadmills are often used in the analysis of walking and running gait to overcome small capture volumes, but their use is believed to induce gait adaptations, such as increased time in stance phase that normally would not happen over ground running.(Dugan & Bhat, 2005) The changes in gait seem to be speed dependent, with walking eliciting little or no change,(Riley, Paolini, Della Croce, Paylo, & Kerrigan, 2007) while changes in running gait appear by the subjects running style speed and short treadmill interaction.(Nigg & Morlock, 1987) The speed of gait can be classified into

jogging (3.31m/s), running (4.77 m/s) and sprinting (10.8 m/s).(Chan & Rudins, 1994) As the speed of gait increases a third phase is introduced, the non-supportive "float" phase, where the two limbs are in mid-air, (stance phase decreases as the swing and float phases increase).(Chan & Rudins, 1994) The period of time spent in stance phase from walking to sprinting decreases from 0.62 seconds to 0.14 seconds.(Mann, Moran, & Dougherty, 1986) The running cycle is a dynamic combination of joints and muscles acting together in order to produce fluid locomotion.(Chan & Rudins, 1994) One of the most basic actions of the foot is pronation and supination.(Chan & Rudins, 1994) Running at a six minute per mile pace, pronation of the foot is completed in 30 milliseconds (ms), about 5 times faster than during walking.(Chan & Rudins, 1994) Pronation is one of the mechanisms for absorbing shock; thus runners with pes cavus (high-arch) feet absorb force less than those with lower arches.(Chan & Rudins, 1994) Running barefoot could result in increased pronation from changes in biomechanics because the body has to absorb shock differently that otherwise would be dissipated by the footwear.(Williams, 1985) After maximal pronation occurs, the foot will start to supinate.(Chan & Rudins, 1994) After the foot has been fully loaded and center of gravity has passed base of support, external rotation of the lower extremity causes inversion of the calcaneus and makes the foot become more rigid.(Mann, Baxter, & Lutter, 1981) During running there is dorsiflexion of the ankle upon heel strike, where as in walking there is plantar flexion upon heel strike.(Chan & Rudins, 1994) With an understanding of these factors, clinicians should be better able to evaluate the foot for problems.(Chan & Rudins, 1994)

Static Measure of Arch Height

Arch Index

The arch height is considered to be an important determinant in the function of the lower limb and foot.(Saltzman, Nawoczenski, & Talbot, 1995) Frequently, footprint parameters are employed in gait studies to indirectly measure arch height, and classify the foot structure.(Hogan & Staheli, 2002) There are several footprint parameters cited in the literature, but the arch index cited by Cavanagh and Rodgers (1987) has received great attention since the inception in the 1980's.(Cavanagh & Rodgers, 1987) The footprint represents the ratio of the area of the middle third of the footprint relative to the total area of the foot minus the toes.(Wearing, Hills, Byrne, Hennig, & McDonald, 2004) The arch index has been used primarily to evaluate the role of the arch height on lower extremity dysfunction and overuse injuries.(Duffey, Martin, Cannon, Craven, & Messier, 2000) However, the validity of employing the arch index as an indirect measure of the arch height is controversial.(Wearing et al., 2004) Several studies have mentioned a moderate correlation between the arch index and either clinical or radiographic measure of arch height,(Chu, Lee, Chu, Wang, & Lee, 1995) and other investigations have identified no significant correlation between the footprint and clinical measures of arch height.(Hawes, Nachbauer, Sovak, & Nigg, 1992) Hawes and colleagues (1992) (Hawes et al., 1992) conducted the largest study to date, and they concluded that the variability in tissue thickness beneath the foot effectively invalidates the use of the arch index as a measure of arch height. With all the ongoing controversy, footprint parameters, including arch index, have been used to evaluate the structure of the foot during growth and development(Forriol & Pascual, 1990) as well as childhood obesity.(Dowling, Steele, & Baur, 2001) Glimour and Burns(Gilmour & Burns, 2001) stated that measures of arch

index were significantly altered by childhood obesity, while direct clinical measures of arch height were not altered.

Footprint parameters are a useful and valid measure of arch height with the gait related research.(Wearing et al., 2004) The arch index has received scientific attention and has allowed clinicians and researchers to classify static arch measures as either high (<0.21), low (>0.26), or normal (0.21-0.26).(Cavanagh & Rodgers, 1987) There has been support for the use of the arch index by demonstrating an association between clinical, and radiographic measurements of arch height.(Chu et al., 1995) However arch height using arch index has only accounted for 45-55% of the variance in the arch.(Chu et al., 1995; McCrory, 1997) The increased pressure on the bottom of the midfoot was reflected as reduced strength of the ligamentous support of the arch, caused by excessive loading and extra weight.(Wearing et al., 2004) Schie and Boulton 2000, in a current study found that body weight was not significantly associated with arch index values even in obese individuals.(Wearing et al., 2004) Body weight was positively correlated with the contact area of the entire foot, as well as the regional sites.(Wearing et al., 2004) Since arch index is an indicator measure of arch height, it is not known if the trend between high weight and low arch index values reflect a high arched foot or distortion of the footprint.(Wearing et al., 2004) Pressure platforms provide a method for collecting footprint data, the accuracy is dependent on the sensor resolution and sensitivity of the equipment used.(Urry, 2001a) Arch height and arch index values collected on force platforms have been shown to be highly correlated to the ink measurement of arch height.(Urry, 2001b) Sensors influence the accuracy of electronic footprints, walking speed has shown to have an effect on plantar pressure measurements.(Hughes, Pratt,

Linge, Clark, & Klenerman, 1991) Cavanagh and Rodgers (1987) demonstrated that change in gait speed from walking to running increased arch index values by 10%, which indicates that faster speed of movement resulted in greater midfoot contact.(Cavanagh & Rodgers, 1987) Wearing and colleagues 2004 found there is no association between stance phase duration and arch index values (r=-02, p=.91).

Sit-to-stand

Since the navicular drop test is not a very reliable test for foot pronation, a new test needed to be made to help account for the poor reliability.(McPoil et al., 2008) Hoppenfeld named the test a "test for rigid or supple feet" which the clinician observed the patients feet while sitting to standing.(McPoil et al., 2008) Hoppenfeld and colleagues stated that if the medial longitudinal arch was absent in both sitting and standing, the patient had rigid feet. They also noted that if the medial longitudinal arch is present in sitting, but absent in standing then the patient had supple feet.(Hoppenfeld, 1976) The sit to stand test is described by Hoppenfeld as an observational exam only.(Hoppenfeld, 1976) The change in the medial longitudinal arch, measured by the change in dorsal arch height, can be quantified during the "Sit-to-Stand" test.(McPoil et al., 2008) The advantage of the "Sit-to-Stand" test helps counter act the low reliability score of the navicular drop test, because there is no need to place the foot in subtalar neutral or identify the navicular tuberosity.(McPoil et al., 2008)

If the "Sit-to-Stand" test can demonstrate acceptable levels of reliability and validity, this test can be an alternative method to assess foot mobility for clinicians and researchers.(McPoil et al., 2008) The decrease in the arch height for all participants from non-weight bearing to 50% weight bearing was 1.00cm.(McPoil et al., 2008) Intra-rater

reliability Intra Class Correlation (ICC) values for foot length, arch height, and change in arch height for all raters was from .73-.99 with standard error of measure (SEM) values ranging from .06-.19 centimeters. Inter-rater reliability ICC values from the same measurements ranged from .73-.98 with SEM values ranging from .07-.16 centimeters.(McPoil et al., 2008) This test prevents the navicular drop test from being used as a measurement tool in studies where numerous clinicians at different clinical sites are required to collect data.(McPoil et al., 2008) The findings of this study show the difference in the arch height in non-weight bearing and arch height in 50% weight bearing as measured using "Sit-to-Stand" provides clinicians with a reliable and valid alternative to quantify foot mobility compared to the navicular drop test.(McPoil et al., 2008)

Navicular Drop Test

The navicular drop test has been used as a clinical method to assess foot mobility and pronation.(Loudon et al., 1996; McPoil et al., 2008) Brody was one of the first to explain the navicular drop test.(Brody, 1982) Brody stated that the navicular drop test is performed with the patient standing on a firm surface with the navicular tuberosity palpated and marked with ink bilaterally.(Brody, 1982) The patient's subtalar joint was placed into neutral, where the talar head could be palpated on the medial and lateral side of the joint.(Brody, 1982; Loudon et al., 1996) The height of the navicular tuberosity to the floor is marked on an index card.(Brody, 1982; Loudon et al., 1996) The patient is then instructed to relax both feet resulting in a lower position of the navicular tuberosity, and then the height of the navicular tuberosity was marked on the index card.(Brody, 1982; Loudon et al., 1996) To determine the measure of navicular drop Brody stated the

height of the navicular bone in subtalar neutral is subtracted from the height of the navicular tuberosity in a relaxed position.(Brody, 1982)

In his examination, Brody indicated that the navicular drop test is an office procedure that is used to assess amount of foot pronation, but failed to provide normative data.(Brody, 1982) It has been reported by multiple studies that the typical range of navicular drop is between 5 and 9mm, values less than 4mm represents a high arch (pes cavus), and 10mm represents a low arch (pes planus).(Brody, 1982; Michelson, 2003) Navicular drop measures that are greater than 9mm have been associated with the development of shin splints,(Delacerda, 1980) while greater than 13mm predisposes runners to anterior cruciate ligament injuries.(Beckett et al., 1992) Brody also did not indicate whether the navicular drop had high or low levels of intra and inter-rater reliability.(Brody, 1982) However, several studies have measured intra and inter-rater reliability of navicular drop. Picciano and colleagues (1993) measured reliability of the navicular drop, and found intra-tester interclass correlations (ICC) of .61-.79, and an inter-tester ICC value of .57.(Picciano et al., 1993) In the study of Loudon and colleagues (1996) measured ICC values for intra-tester navicular drop and received an ICC value of .76.(Loudon et al., 1996)

Placing the subtalar joint in neutral position and correctly palpating and marking the navicular tuberosity are the sources of error for the navicular drop test.(Picciano et al., 1993) The intra-tester ICC value for the OKC measure in subtalar joint neutral is .06-.27, and the inter-tester ICC value was .00.(Picciano et al., 1993) The intra-tester ICC value for the CKC measure in subtalar joint neutral is .14-.18, and the inter-tester ICC value was .15.(Picciano et al., 1993) Reasons for the low reliability of the OKC and CKC

of subtalar joint neutral may be attributed to inexperienced testers, and difficulty of coming to an accurate bisection of the talar joint.(Picciano et al., 1993) For it to be a more reliable clinical measure, clinicians will need to practice the measurements to become more experienced, which will result in better reliability.(Picciano et al., 1993)

Dynamic Measure of Arch Height

Navicular Drop During Running

In a study conducted by Eslami and colleagues (2014), 16 men with no history of injury were recruited.(Eslami et al., 2014) To determine the correlation between navicular drop and biomechanical variables, subjects were selected with a navicular measurement between 3 and 12mm.(Eslami et al., 2014) The static measure of navicular drop was measured by the method proposed by Loundon and colleagues 1996.(Loudon et al., 1996) Three measurements of navicular drop were taken, and the average was used for that participant.(Eslami et al., 2014) A six-camera motion capture system was used with two arcs on each side of a force plate located in the middle of a 10m runway.(Eslami et al., 2014) Nine reflective markers were placed over the right foot and tibia. (Eslami et al., 2014) Ten running trials were performed bearfoot and the subjects ran at a cadence of 170 steps per minute controlled by a metronome.(Eslami et al., 2014)

A pearson correlation and scatter plot analysis were performed to determine if the dependent variables were correlated with the navicular drop measures. (Eslami et al., 2014) There was a significant correlation between navicular drop and peak knee adduction ($P<.01$).(Eslami et al., 2014) Navicular drop was negatively correlated with tibial internal rotation excursion but not with rearfoot eversion.(Eslami et al., 2014) Busseuil and colleagues (1998) state that excessive tibial internal rotation results in

abnormal movement in the foot, and these abnormal motions are thought to lead to shin splints.(Busseuil, Freychat, Guedj, & Lacour, 1998) The results of this study suggest that navicular drop measures are associated with increased tibial rotation, which can lead to shin and knee injuries during running. (Eslami et al., 2014) A limitation of this study is that it only examined running at a certain cadence, and this cannot be generalized to different running speeds.(Eslami et al., 2014) Future studies need to look at different speeds and gait, as well as using clinical populations.(Eslami et al., 2014)

Navicular Drop During Walking

In a study conducted from Nielsen and colleagues (2009), 280 participants volunteered, and were only included if they had no lower extremity deformities, major trauma, and no pain in the lower extremity in the last three months. (Nielsen, Rathleff, Simonsen, & Langberg, 2009) Foot length was measured with a ruler from the calcaneus to the tip of the longest toe.(Nielsen et al., 2009) Reflective flat markers were used, and placed on the navicular tuberosity, medial aspect of the calcaneus, and medial aspect of the first metatarsal head while seated and the foot in subtalar neutral.(Nielsen et al., 2009) The participants were instructed to walk barefoot on a treadmill at a self-selected pace, and twenty consecutive steps were recorded for analysis.(Nielsen et al., 2009) A 2D motion capture system was used to measure navicular drop during walking, which consisted of a digital camera with a 12 mm lens sampling at 86 Hz.(Nielsen et al., 2009)

Navicular drop was calculated as the perpendicular distance between the marker on the navicular tuberosity and the line between the markers on the calcaneus and the first toe.(Nielsen et al., 2009) The system used for data capturing was deemed reliable with a test/retest ICC value of .95.(Nielsen et al., 2009) A pearson correlation as well as

multiple regression techniques were applied to test for relationships between parameters.(Nielsen et al., 2009)

Dynamic navicular drop ranged from 1.7-13.4mm, and 95% of the population had a navicular drop less than 8.7mm.(Nielsen et al., 2009) A positive correlation was found between foot length and dynamic naviciular drop.(Nielsen et al., 2009) Nielsen and colleagues (2009), investigated the influence of foot length, age, gender, and BMI on the dynamic measure of navicular drop.(Nielsen et al., 2009) As the foot length increases from 22-28cm, the upper value of abnormal navicular drop increases from 7.25mm to 9.50mm for males, and 7.8mm to 10mm for females. The current study demonstrates that dynamic navicular drop is influenced by foot length and gender.(Nielsen et al., 2009) A limitation is that the study only looked at walking at a self selected pace, and the results can not be generalized to different speeds and gait parameters.(Nielsen et al., 2009) Future studies should adjust for foot length and gender as well as different locomotion styles when examining navicular drop.(Nielsen et al., 2009)

Dynamic Arch Index

In a study conducted by Teyhen and colleagues (2009) looked a dynamic measure of arch index during walking gait. (Teyhen et al., 2009) They conducted static measures of arch height and foot length while standing.(Teyhen et al., 2009) Heel to toe length was measured as the distance from the heel to the longest toe measured by a ruler and a sliding bar.(Teyhen et al., 2009) Dorsal arch height was measured using a vertical digital caliper form the platform to the dorsal surface of the foot.(Teyhen et al., 2009) To assess potential plantar pressure patterns associated with static arch height, a capacitance-based pressure platform was used.(Teyhen et al., 2009) Participants were directed to walk

barefoot across the platform at a self-selected pace, and the second step following gait initiation was recorded from heel strike to toe-off.(Teyhen et al., 2009) This was repeated until 10 passes were recorded, and a trial was repeated if the entire footprint was not recorded.(Teyhen et al., 2009)

Univariate Pearson correlation coefficients were calculated for static arch height and plantar pressure parameters.(Teyhen et al., 2009) Of the 693 subjects, 69.3% were classified as having a normal arch, 82 8.2%, and 60, 6.0% were classified with a high arch or extremely high arch respectively.(Teyhen et al., 2009) 110 11.0% and 55 5.5% of the subjects were classified with a low arch or extremely low arch respectively.(Teyhen et al., 2009) The results of this study provide a biomechanically plausible multivariate model to provide the association between arch height and plantar pressure during gait.(Teyhen et al., 2009) The model in this study provides support for the use if the arch height index values as a clinical measure to estimate the dynamic activity of the foot during gait.(Teyhen et al., 2009) A limitation of this study is they walked at a self selected pace, and only looked at two steps.(Teyhen et al., 2009) Future studies should look at different walking speeds and more inclusive gait patterns, as well as assess which variables may be linked to increased injury incidence of injury with individuals with extreme arch heights.(Teyhen et al., 2009)

Conclusion

The height of the arch is an important determinant in the function of the lower limb.(Saltzman et al., 1995) The foot is a unique structure that can serve two functions, supporting the weight of the body, as well as locomotion.(Bramble & Lieberman, 2004; Franco, 1987) There are a few static tests and procedures that can be done in order to

measure arch height of the foot. The arch height index is used to look at arch height and foot structure.(Hogan & Staheli, 2002) The sit to stand test is an observational study to see of the patient has rigid or supple feet.(Hoppenfeld, 1976; McPoil et al., 2008) The navicular drop test can test for pronation of the foot when the foot is in subtalar neutral and a relaxed position.(Brody, 1982) With all of these static measures of arch height, and some with poor reliability, none of these procedures has emerged as the clinical gold standard for measuring arch height and pronation of the foot. Some studies have studied these measures in a dynamic setting while walking and running. In a study by Nielson and colleagues (2009), they compared navicular drop to foot length, and found navicular drop is positively correlated with foot length.(Nielsen et al., 2009) In another dynamic study conducted by Eslami and colleagues (2014), they studied navicular drop during the stance phase of running.(Eslami et al., 2014) This study found navicular drop was positively correlated with knee adduction.(Eslami et al., 2014) However, if the static measure of navicular drop can predict lower extremity dysfunction(Beckett et al., 1992; Delacerda, 1980), few studies to date have directly looked at the correlation of the static measure of navicular drop to a dynamic measure.

REFERENCES

Beckett, M. E., Massie, D. L., Bowers, K. D., & Stoll, D. A. (1992). Incidence of Hyperpronation in the ACL Injured Knee: A Clinical Perspective. *J Athl Train, 27*(1), 58-62.

Beischer, A. D., Brodsky, J. W., Pollo, F. E., & Peereboom, J. (1999). Functional outcome and gait analysis after triple or double arthrodesis. *Foot Ankle Int, 20*(9), 545-553.

Bramble, D. M., & Lieberman, D. E. (2004). Endurance running and the evolution of Homo. *Nature, 432*(7015), 345-352. doi: 10.1038/nature03052

Brodsky, J. W., Baum, B. S., Pollo, F. E., & Mehta, H. (2007). Prospective gait analysis in patients with first metatarsophalangeal joint arthrodesis for hallux rigidus. *Foot Ankle Int, 28*(2), 162-165. doi: 10.3113/FAI.2007.0162

Brody, D. M. (1982). Techniques in the evaluation and treatment of the injured runner. *Orthop Clin North Am, 13*(3), 541-558.

Brown, C. N., & Mynark, R. (2007). Balance deficits in recreational athletes with chronic ankle instability. *J Athl Train, 42*(3), 367-373.

Busseuil, C., Freychat, P., Guedj, E. B., & Lacour, J. R. (1998). Rearfoot-forefoot orientation and traumatic risk for runners. *Foot Ankle Int, 19*(1), 32-37.

Carson, M. C., Harrington, M. E., Thompson, N., O'Connor, J. J., & Theologis, T. N. (2001). Kinematic analysis of a multi-segment foot model for research and clinical applications: a repeatability analysis. *J Biomech, 34*(10), 1299-1307.

Cavanagh, P. R., & Rodgers, M. M. (1987). The arch index: a useful measure from footprints. *J Biomech, 20*(5), 547-551.

Chan, C. W., & Rudins, A. (1994). Foot biomechanics during walking and running. *Mayo Clin Proc, 69*(5), 448-461.

Chu, W. C., Lee, S. H., Chu, W., Wang, T. J., & Lee, M. C. (1995). The use of arch index to characterize arch height: a digital image processing approach. *IEEE Trans Biomed Eng, 42*(11), 1088-1093. doi: 10.1109/10.469375

Cohen, S. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd. ed.). London ; New York: Routledge.

Cooper, D. (1979). Managing the pronated foot. *The Physician and Sportsmedicine, 7*(5), 131.

Daniels, T., & Thomas, R. (2008). Etiology and biomechanics of ankle arthritis. *Foot Ankle Clin, 13*(3), 341-352, vii. doi: 10.1016/j.fcl.2008.05.002

Davis, R. B. (1997). Reflections on clinical gait analysis. *J Electromyogr Kinesiol, 7*(4), 251-257.

De Clercq, D., Aerts, P., & Kunnen, M. (1994). The mechanical characteristics of the human heel pad during foot strike in running: an in vivo cineradiographic study. *J Biomech, 27*(10), 1213-1222.

Delacerda, F. G. (1980). A study of anatomical factors involved in shinsplints. *J Orthop Sports Phys Ther, 2*(2), 55-59. doi: 10.2519/jospt.1980.2.2.55

Dowling, A. M., Steele, J. R., & Baur, L. A. (2001). Does obesity influence foot structure and plantar pressure patterns in prepubescent children? *Int J Obes Relat Metab Disord, 25*(6), 845-852. doi: 10.1038/sj.ijo.0801598

Duffey, M. J., Martin, D. F., Cannon, D. W., Craven, T., & Messier, S. P. (2000). Etiologic factors associated with anterior knee pain in distance runners. *Med Sci*

Sports Exerc, 32(11), 1825-1832.
Dugan, S. A., & Bhat, K. P. (2005). Biomechanics and analysis of running gait. *Phys Med Rehabil Clin N Am, 16*(3), 603-621. doi: 10.1016/j.pmr.2005.02.007
Egloff M, H., H. (2015). Comparison of Manual and Digital Measurement of the Navicular Drop in Two Different Procedures. *Physiotherapy, 101*.
Eichelberger, J. G. (2015). Reliability of a New Foot Model for Dynamic Navicular Drop Measurement *Physiotherapy, 101*, 346.
Eslami, M., Damavandi, M., & Ferber, R. (2014). Association of navicular drop and selected lower-limb biomechanical measures during the stance phase of running. *J Appl Biomech, 30*(2), 250-254. doi: 10.1123/jab.2011-0162
Forriol, F., & Pascual, J. (1990). Footprint analysis between three and seventeen years of age. *Foot Ankle, 11*(2), 101-104.
Franco, A. H. (1987). Pes cavus and pes planus. Analyses and treatment. *Phys Ther, 67*(5), 688-694.
Gilmour, J. C., & Burns, Y. (2001). The measurement of the medial longitudinal arch in children. *Foot Ankle Int, 22*(6), 493-498.
Hawes, M. R., Nachbauer, W., Sovak, D., & Nigg, B. M. (1992). Footprint parameters as a measure of arch height. *Foot Ankle, 13*(1), 22-26.
Higginson, B. K. (2009). Methods of running gait analysis. *Curr Sports Med Rep, 8*(3), 136-141. doi: 10.1249/JSR.0b013e3181a6187a
Hogan, M. T., & Staheli, L. T. (2002). Arch height and lower limb pain: an adult civilian study. *Foot Ankle Int, 23*(1), 43-47.
Hoppenfeld, S. (1976). *Physical Examination of the Spine and Extremities* New York: Appleton-Century-Crofts.
Hughes, J., Pratt, L., Linge, K., Clark, P., & Klenerman, L. (1991). Reliability of pressure measurements: the EM ED F system. *Clin Biomech (Bristol, Avon), 6*(1), 14-18. doi: 10.1016/0268-0033(91)90036-P
Hunter S, B. G. (2000). <Subtalar joint neutral and orthotic fitting.pdf>. *Athletic therapy Today, 5*(1), 6-9.
Ker, R. F., Bennett, M. B., Bibby, S. R., Kester, R. C., & Alexander, R. M. (1987). The spring in the arch of the human foot. *Nature, 325*(7000), 147-149. doi: 10.1038/325147a0
Kirby, K. A. (2000). Biomechanics of the normal and abnormal foot. *J Am Podiatr Med Assoc, 90*(1), 30-34. doi: 10.7547/87507315-90-1-30
Leardini, A., Benedetti, M. G., Berti, L., Bettinelli, D., Nativo, R., & Giannini, S. (2007). Rear-foot, mid-foot and fore-foot motion during the stance phase of gait. *Gait Posture, 25*(3), 453-462. doi: 10.1016/j.gaitpost.2006.05.017
Lippincott, Williams, D. G., & Wilkins. (2014). ACSM GUidelines for Exercise Testing and Prescription. *61*(3), 8-43. doi: 10.1016/j.biopsych.2006.04.007
Loudon, J. K., Jenkins, W., & Loudon, K. L. (1996). The relationship between static posture and ACL injury in female athletes. *J Orthop Sports Phys Ther, 24*(2), 91-97. doi: 10.2519/jospt.1996.24.2.91
Mann, R. A., Baxter, D. E., & Lutter, L. D. (1981). Running symposium. *Foot Ankle, 1*(4), 190-224.
Mann, R. A., Moran, G. T., & Dougherty, S. E. (1986). Comparative electromyography of the lower extremity in jogging, running, and sprinting. *Am J Sports Med, 14*(6),

501-510.
Mayich, D. J., Novak, A., Vena, D., Daniels, T. R., & Brodsky, J. W. (2014). Gait analysis in orthopedic foot and ankle surgery--topical review, part 1: principles and uses of gait analysis. *Foot Ankle Int, 35*(1), 80-90. doi: 10.1177/1071100713508394
McCrory, J. Y., MJ. Boulton, AJM. Cavannagh, PR. (1997). Arch index as a predictor of arch height. *Foot Ankle*(7), 79-81.
McPoil, T. G., & Cornwall, M. W. (1996). The relationship between static lower extremity measurements and rearfoot motion during walking. *J Orthop Sports Phys Ther, 24*(5), 309-314. doi: 10.2519/jospt.1996.24.5.309
McPoil, T. G., Cornwall, M. W., Medoff, L., Vicenzino, B., Forsberg, K., & Hilz, D. (2008). Arch height change during sit-to-stand: an alternative for the navicular drop test. *J Foot Ankle Res, 1*(1), 3. doi: 10.1186/1757-1146-1-3
McPoil, T. G., & Knecht, H. G. (1985). Biomechanics of the foot in walking: a function approach. *J Orthop Sports Phys Ther, 7*(2), 69-72.
Michelson, J. D., DM. McFarland, E. (2003). Injury Risk Associated with Pes Planus in Athletes. *Foot Ankle Int, 23*(7), 629-633.
Mohammed, S. S., A. Oukhellou, L. Kong, K. (2016). Recognition of Gait Cycle Phases Using Wearable Sensors. *Robotics and Autonomous, 75*, 50-59.
Mueller, M. J., Host, J. V., & Norton, B. J. (1993). Navicular drop as a composite measure of excessive pronation. *J Am Podiatr Med Assoc, 83*(4), 198-202. doi: 10.7547/87507315-83-4-198
Mummolo, C., Mangialardi, L., & Kim, J. H. (2013). Quantifying dynamic characteristics of human walking for comprehensive gait cycle. *J Biomech Eng, 135*(9), 91006. doi: 10.1115/1.4024755
Nielsen, R. G., Rathleff, M. S., Simonsen, O. H., & Langberg, H. (2009). Determination of normal values for navicular drop during walking: a new model correcting for foot length and gender. *J Foot Ankle Res, 2*, 12. doi: 10.1186/1757-1146-2-12
Nigg, B. M., & Morlock, M. (1987). The influence of lateral heel flare of running shoes on pronation and impact forces. *Med Sci Sports Exerc, 19*(3), 294-302.
Picciano, A. M., Rowlands, M. S., & Worrell, T. (1993). Reliability of open and closed kinetic chain subtalar joint neutral positions and navicular drop test. *J Orthop Sports Phys Ther, 18*(4), 553-558. doi: 10.2519/jospt.1993.18.4.553
Qian, Z., Ren, L., & Ren, L. (2010). A Coupling Analysis of the Biomechanical Functions of Human Foot Complex during Locomotion. *Journal of Bionic Engineering, 4*, 150-157.
Riley, P. O., Paolini, G., Della Croce, U., Paylo, K. W., & Kerrigan, D. C. (2007). A kinematic and kinetic comparison of overground and treadmill walking in healthy subjects. *Gait Posture, 26*(1), 17-24. doi: 10.1016/j.gaitpost.2006.07.003
Rolian, C., Lieberman, D. E., & Hallgrimsson, B. (2010). The coevolution of human hands and feet. *Evolution, 64*(6), 1558-1568. doi: 10.1111/j.1558-5646.2010.00944.x
Saltzman, C. L., Nawoczenski, D. A., & Talbot, K. D. (1995). Measurement of the medial longitudinal arch. *Arch Phys Med Rehabil, 76*(1), 45-49.
Seeley, R. V., C. Regan, J. Russo, A. (2008). *Seeley's Anatomy & Physiology*. New York, NY: McGraw Hill Companies.

Shultz, R., Kedgley, A. E., & Jenkyn, T. R. (2011). Quantifying skin motion artifact error of the hindfoot and forefoot marker clusters with the optical tracking of a multi-segment foot model using single-plane fluoroscopy. *Gait Posture, 34*(1), 44-48. doi: 10.1016/j.gaitpost.2011.03.008

Subotnick, S. (1980). The cavus foot. *The Physician and Sportsmedicine, 8*(7), 53-55.

Taunton, J. E., Ryan, M. B., Clement, D. B., McKenzie, D. C., Lloyd-Smith, D. R., & Zumbo, B. D. (2002). A retrospective case-control analysis of 2002 running injuries. *Br J Sports Med, 36*(2), 95-101.

Teyhen, D. S., Stoltenberg, B. E., Collinsworth, K. M., Giesel, C. L., Williams, D. G., Kardouni, C. H., . . . McPoil, T. (2009). Dynamic plantar pressure parameters associated with static arch height index during gait. *Clin Biomech (Bristol, Avon), 24*(4), 391-396. doi: 10.1016/j.clinbiomech.2009.01.006

Urry, S. W., SC. (2001a). The accuracy of footprint contact area measurements: relevance to the design and performance of pressure platforms. *Foot Ankle*(11), 151-157.

Urry, S. W., SC. (2001b). A comparison of footprint indexes calculated from ink and electronic footprints. *Journal of American Podiatrist Medical Association*(91), 203-209.

Wearing, S. C., Hills, A. P., Byrne, N. M., Hennig, E. M., & McDonald, M. (2004). The arch index: a measure of flat or fat feet? *Foot Ankle Int, 25*(8), 575-581.

Whittle, M. (1996). Clinical Gait Analysis: A review. *Human Movement Science*(15), 369-387.

Williams, K. R. (1985). Biomechanics of running. *Exerc Sport Sci Rev, 13*, 389-441.

Wright, W. G., Ivanenko, Y. P., & Gurfinkel, V. S. (2012). Foot anatomy specialization for postural sensation and control. *J Neurophysiol, 107*(5), 1513-1521. doi: 10.1152/jn.00256.2011

Yates, B., Allen, M. J., & Barnes, M. R. (2003). Outcome of surgical treatment of medial tibial stress syndrome. *J Bone Joint Surg Am, 85-A*(10), 1974-1980.